UNITED
NATIONS

A

General Assembly

Distr.
GENERAL

A/45/373
18 September 1990

ORIGINAL: ENGLISH

Forty-fifth session
Item 58 (b) of the provisional
agenda*

GENERAL AND COMPLETE DISARMAMENT

Comprehensive study on nuclear weapons

Report of the Secretary-General

1. By its resolution 43/75 N of 7 December 1988, the General Assembly requested the Secretary-General to carry out, with the assistance of qualified governmental experts and taking into account recent relevant studies, a comprehensive update of the Comprehensive Study on Nuclear Weapons [1] that would provide factual and up-to-date information on and would pay regard to the political, legal and security aspects of: (a) nuclear arsenals and pertinent technological developments; (b) doctrines concerning nuclear weapons; (c) efforts to reduce nuclear weapons; (d) physical, environmental, medical and other effects of use of nuclear weapons and of nuclear testing; (e) efforts to achieve a comprehensive nuclear-test ban; (f) efforts to prevent the use of nuclear weapons and their horizontal and vertical proliferation; (g) the question of verification of compliance with nuclear-arms limitation agreements; and recommended that the study, while aiming at being as comprehensive as possible, should be based on open material and such further information as Member States might wish to make available for the purpose of the study. The Assembly further requested the Secretary-General to submit the final report to it well in advance of its forty-fifth session.

2. Pursuant to that resolution, the Secretary-General has the honour to transmit to the General Assembly the comprehensive study on nuclear weapons.

---

* A/45/150 and Corr.1.

[1] United Nations publication, Sales No. E.81.I.11.

best copy available

ANNEX

Comprehensive study on nuclear weapons

CONTENTS

		Paragraphs	Page
FOREWORD BY THE SECRETARY-GENERAL			5
LETTER OF TRANSMITTAL			7
I.	INTRODUCTION	1 - 10	10
II.	EXISTING NUCLEAR WEAPONS: TECHNICAL DATA AND STATISTICS	11 - 101	13
	A. Introduction	11 - 14	13
	B. Short description of physical properties of nuclear weapons	15 - 31	15
	C. Categories of nuclear weapons	32 - 43	17
	D. Nuclear weapon arsenals	44 - 81	19
	E. Systems for command and control of nuclear forces	82 - 101	24
III.	TRENDS IN THE TECHNOLOGICAL DEVELOPMENT OF NUCLEAR-WEAPON SYSTEMS	102 - 172	31
	A. General	102 - 104	31
	B. Main features of past developments	105 - 133	31
	C. Main features of new developments	134 - 156	36
	D. Ballistic missile defence systems and countermeasures	157 - 172	39
IV.	DOCTRINES AND STRATEGIES CONCERNING NUCLEAR WEAPONS	173 - 232	45
	A. General	173 - 180	45
	B. Doctrines of the nuclear-weapon States	181 - 213	46
	C. Relationship between nuclear weapons, non-nuclear weapons and deterrence	214 - 225	52
	D. Differing positions regarding nuclear deterrence	226 - 232	55

/...

CONTENTS (continued)

		Paragraphs	Page
V.	DEVELOPMENT, PRODUCTION AND TESTING OF NUCLEAR WEAPONS ...	233 - 287	61
	A. Decision-making regarding the development and testing of nuclear weapons	233 - 235	61
	B. Nuclear testing and its relationship to the continued development of warheads	236 - 240	61
	C. Costs of acquiring and maintaining nuclear weapons ...	241 - 248	63
	D. Peaceful uses of nuclear explosive devices	249 - 256	64
	E. Physical, medical and environmental effects of nuclear weapons production	257 - 269	66
	F. Physical, medical and environmental effects of testing	270 - 287	68
VI.	EFFECTS OF USE OF NUCLEAR WEAPONS AND CONSEQUENCES OF NUCLEAR WAR	288 - 355	75
	A. General	288 - 291	75
	B. Effects of one nuclear explosion	292 - 305	75
	C. Levels of immediate destruction in various scenarios .	306 - 322	80
	D. Medical effects	323 - 339	85
	E. Environmental and other global effects	340 - 350	88
	F. Possible protective measures	351 - 355	91
VII.	NUCLEAR WEAPONS AND INTERNATIONAL SECURITY	356 - 421	97
	A. Nuclear weapons and security concepts	356 - 366	97
	B. International security and quantitative and qualitative development of nuclear weapons	367 - 378	99
	C. International security and possible emergence of new nuclear-weapon States	379 - 396	101
	D. International security and geographical spread of nuclear weapons	397 - 409	104
	E. Prevention of accidental use of nuclear weapons	410 - 421	106

/...

CONTENTS (continued)

		Paragraphs	Page
VIII.	NUCLEAR ARMS LIMITATION AND DISARMAMENT	422 - 513	112
	A. Introduction	422 - 423	112
	B. Constraints on the possession of nuclear weapons	424 - 442	112
	C. Limitation on stationing of nuclear weapons	443 - 450	116
	D. Limitations and reductions of nuclear weapons	451 - 470	118
	E. Limitation on testing of nuclear explosive devices	471 - 480	122
	F. Constraints on the use of nuclear weapons	481 - 501	125
	G. Confidence-building measures	502 - 505	129
	H. Nuclear weapons and international law	506 - 513	130
IX.	CONCLUSIONS	514 - 538	135

APPENDICES

		Page
I.	Official doctrinal positions of the nuclear-weapon States	139
II.	Land- and sea-based nuclear weapons	147

READEX FICHE

/...

FOREWORD BY THE SECRETARY-GENERAL

When in 1988 the General Assembly adopted resolution 43/75 N requesting an update of the 1980 Comprehensive Study on Nuclear Weapons, very few could have anticipated that the carrying out of this new mandate would in time coincide with, and in fact run parallel to, far-reaching changes in international relations arising not least from an unprecedented evolution in the relationship between East and West. The passing of the cold war has seen a genuine relaxation of tension between the principal military alliances, accompanied by the development of wide-ranging confidence-building measures, many of them regarding military and security matters. In fact, the nuclear age has, in the period under review, experienced for the first time the initiation of an effective process of reduction of nuclear weapon stockpiles.

These circumstances are in strong contrast to those which obtained at the time of the preparation of the earlier study. While there can be no serious suggestion that the broad aims of the Charter have been realized overnight, there has nonetheless been an evolution in the context for consideration of the subject-matter at hand. The questions of nuclear weapons, strategic doctrines and security concepts, and the future role of nuclear weapons as they relate to the maintenance of international peace and security must now be placed against this evolving background.

The present study represents the most comprehensive review of the relevant developments in this field over the past decade or so. It also covers recent events, which were unfolding while the Group of Experts was finalizing the text of the study. Thus, the study deals in its analyses with the documents adopted at the summit meetings of the Warsaw Treaty Organization and NATO held in June and July 1990 respectively, which contain statements of political and military significance for the entire range of issues related to nuclear weapons and strategic doctrines. The study moreover takes into account the results of the summit meeting held between President Bush of the United States and President Gorbachev of the Soviet Union in June 1990 in Washington, at which important agreements in principle were reached for significant reductions in strategic offensive nuclear forces of the two nuclear-weapon Powers.

The study contains several significant conclusions. One of them is that the quantitative growth of nuclear-weapon arsenals has been stopped. The total number of nuclear warheads in the world has declined and this trend is expected to continue. The danger of nuclear confrontation has been significantly reduced if not eliminated altogether. On the other hand, however, qualitative improvements of nuclear-weapon systems, though confined to several areas, continue without significant restrictions. The question of the cessation of nuclear-weapon tests remains a highly divisive issue in international discussions.

To my mind, while disarmament negotiations regarding nuclear weapons are generally moving in the right direction and, as a result, a nuclear danger is less pronounced today than was the case a decade ago, the main task of the international community in the present realities in international relations remains threefold:

to preserve resolutely the present positive momentum in the negotiations for the reduction of nuclear weapons, with a view to their eventual complete elimination; to find ways and means of effectively curbing the continued qualitative improvements in this field; and to strengthen the barriers against possible proliferation of nuclear weapons to non-nuclear-weapon States. With the process of nuclear disarmament finally begun, it would be against the interests of international peace and security if new nuclear-weapon States should now emerge, just as would be the case if the nuclear-weapon States should fail to capitalize on the positive momentum in international relations to achieve further substantive agreements.

I wish to express my sincere appreciation to the Group of Experts appointed to assist the Secretary-General in carrying out this study, not least for having concluded their work in unanimity. I am indeed grateful to them and I commend the study to the General Assembly for its consideration.

/...

LETTER OF TRANSMITTAL

6 July 1990

Sir,

I have the honour to submit herewith the report of the Group of Experts on a Comprehensive Study on Nuclear Weapons, which was appointed by you in pursuance of paragraph 1 of General Assembly resolution 43/75 N of 7 December 1988.

The Experts appointed by you were the following:

Ambassador Mohamed El-Shaffei Abdel Hamid
Former Under-Secretary of State
Ministry of Foreign Affairs
Cairo, Egypt

Mr. Gustavo Ainchil
General Department of International Security
and Strategic Affairs
Ministry of Foreign Affairs and Worship
Buenos Aires, Argentina

Mr. Alexander Akalovsky
Bureau of Multilateral Affairs
United States Arms Control and Disarmament Agency
Washington, DC, United States of America

Monsieur Gilles Curien
Ambassadeur de France
Ministère des Affaires Etrangères
Paris, France

Dr. Radoslav Deyanov
Advisor on Disarmament Matters
Ministry of Foreign Affairs
Sofia, Bulgaria

Dr. Hedy Hernandez
Minister Counsellor
Department of International Politics
Department of Multilateral Affairs
Ministry of External Relations
Caracas, Venezuela

His Excellency
Mr. Javier Pérez de Cuéllar
Secretary-General of the United Nations
New York

/...

Ambassador Brett Lineham
High Commissioner
New Zealand High Commission
Tarawa, Kiribati

Mr. H. M. G. S. Palihakkara
First Secretary
Permanent Mission of Sri Lanka to the
United Nations Office at Geneva
Geneva, Switzerland

Ambassador Nana Sutresna
Ambassador Extraordinary and Plenipotentiary
Permanent Mission of Indonesia to the United Nations
New York, United States of America

Mr. Cheikh Sylla
Technical Counsellor
Ministère des Affaires Etrangères
Dakar, Senegal

Ambassador Maj Britt Theorin
Chairman of the Swedish Disarmament Delegation
Ministry of Foreign Affairs
Stockholm, Sweden

Professor Henry A. Trofimenko
Chief Analyst
Institute of United States and Canadian Studies
Academy of Sciences of the Union of Soviet Socialist Republics
Moscow, Union of Soviet Socialist Republics

The report was prepared between March 1989 and July 1990, during which period the Group held four sessions, from 6 to 10 March 1989 in New York, 27 November to 6 December 1989 in Geneva, 19 to 28 March 1990 and 27 June to 6 July 1990 in New York.

At the first session of the Group, Dr. Andrei Kokoshin participated as an expert from the Soviet Union. At the first two sessions of the Group, Dr. Nicholas Carrera participated as an expert from the United States and Mr. Ivan Ivanissevich participated as an expert from Argentina.

The members of the Group of Experts wish to express their appreciation for the assistance which they received from members of the Secretariat of the United Nations. They wish, in particular, to convey their gratitude to Mr. Prvoslav Davinic, Chief of the Monitoring, Analysis and Studies Branch of the Department for Disarmament Affairs, and to Ms. Jenifer Mackby, who served as Secretary of the Group. Mr. Jukka Huopaniemi of the Department for Disarmament Affairs served as Secretary of the Group during the first session, and Mr. Ian Cuthbertson served in his private capacity as consultant to the Secretariat for the first draft of the report.

The Group would also like to express its appreciation to Professor Richard Garwin for his presentation at a workshop on the recent technological developments in nuclear weapons, as well as Dr. I. Riaboukhine and Professor Joseph Rotblat for addressing the Group on the health effects of the use of nuclear weapons.

I have been requested by the Group of Experts, as its Chairman, to submit to you on its behalf this report, which was unanimously approved.

Accept, Sir, the assurances of my highest consideration.

(Signed) Maj Britt THEORIN
Chairman of the
Group of Experts on a Comprehensive
Study on Nuclear Weapons

CHAPTER I

INTRODUCTION

1. On 7 December 1988, the General Assembly adopted resolution 43/75 N, the operative paragraphs of which read as follows:

> "*The General Assembly*,
>
> "...
>
> "1. *Requests* the Secretary-General to carry out, with the assistance of qualified governmental experts 1/ and taking into account recent relevant studies, a comprehensive update of the *Comprehensive Study on Nuclear Weapons* that provides factual and up-to-date information on and pays regard to the political, legal and security aspects of:
>
> (a) Nuclear arsenals and pertinent technological developments;
>
> (b) Doctrines concerning nuclear weapons;
>
> (c) Efforts to reduce nuclear weapons;
>
> (d) Physical, environmental, medical and other effects of use of nuclear weapons and of nuclear testing;
>
> (e) Efforts to achieve a comprehensive nuclear-test ban;
>
> (f) Efforts to prevent the use of nuclear weapons and their horizontal and vertical proliferation;
>
> (g) The question of verification of compliance with nuclear-arms limitation agreements;
>
> "2. *Recommends* that the study, while aiming at being as comprehensive as possible, should be based on open material and such further information as Member States may wish to make available for the purpose of the study;
>
> "3. *Invites* all Governments to co-operate with the Secretary-General so that the objectives of the study may be achieved;
>
> "4. *Requests* the Secretary-General to submit the final report to the General Assembly well in advance of its forty-fifth session."

2. The update of the 1980 study 2/ has been prepared against the background of important changes that have occurred in international relations in the last 10 years since its publication. They are characterized by the global quantitative and continued qualitative developments of nuclear weapons on the one hand and major breakthroughs in arms limitation and disarmament negotiations on the other.

/...

3. On the technical level, research, development, production and deployment of new weapons have continued steadily, with the attendant introduction of more accurate nuclear ballistic missile systems and the deployment of highly accurate nuclear-armed cruise missiles. Accuracy, low yield and miniaturization led to MIRVed (MIRV - multiple independently targetable re-entry vehicle) intercontinental ballistic missiles (ICBMs) and the development of new types of cruise missiles - whether sea-, air- or land-launched - at relatively limited costs. The possibility of ballistic missile defence (BMD) technologies based on various concepts is also being explored.

4. In reviewing these developments, the study refers to figures, estimates and other data based on various open academic and other non-governmental sources. Some data are, however, officially published by nuclear-weapon States, though such information is generally classified. The Governments of the respective nuclear-weapon States do not necessarily concur with the data given by non-official sources.

5. In 1990 there are about 50,000 nuclear warheads deployed around the world on the territories of the nuclear-weapon States and some non-nuclear-weapon States, as well as on the high seas. Each of the two major Powers has at least 10,000 nuclear warheads, which can be set into action in a major strategic attack within minutes or hours.

6. The possibility of the development of nuclear weapons by additional States also continues to be a deep concern. The Fourth Review Conference of the Treaty on the Non-Proliferation of Nuclear Weapons will take place at Geneva from 20 August to 14 September 1990. It is the last one before 1995, when a Conference will be held to decide whether the Treaty shall continue in force indefinitely, or shall be extended for an additional fixed period or periods. In addition, there have been recent reports of more countries developing short- and intermediate-range ballistic missiles. These issues may be expected to gain rising attention in the forthcoming months and years of the new decade.

7. The end of the 1980s may have heralded an end to the cold war and the cresting of an escalating arms race that has prevailed for the 45 years since the Second World War. The growing rapprochement between East and West, movement towards settlement of various regional conflicts, important political changes in Europe and other regions of the world and the increasing involvement of the United Nations in major issues facing the international community create favourable opportunities for the pursuit of meaningful measures in arms limitation and disarmament. Indeed, major progress has been made in several areas, both bilaterally between the United States and the Soviet Union and between members of the North Atlantic Treaty Organization and the Warsaw Treaty Organization. Although global stability and peace have not yet been attained, positive developments in international relations continue to gain momentum. These positive trends do not remove the need to continue the urgent search for solutions to regional problems in Asia and Africa so as to preclude the possibility of a conflict and, in particular, to prevent the use of weapons of mass destruction should a conflict nevertheless occur. This matter and its impact on global stability should be accorded the utmost importance.

/...

8. In the same decade the first agreement providing for actual reductions in nuclear weapons, the Treaty between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles (INF Treaty), was signed in 1987. It provides for the elimination of a whole category of nuclear weapons under a system of unprecedented intrusive verification. This Treaty has paved the way for further progress on other arms limitation agreements.

9. The nuclear arms race may be turned around by the strategic offensive arms reduction treaty (START), the basic provisions of which were agreed to by the Soviet Union and the United States in June 1990. The international community has welcomed the agreement on the framework for such a treaty - which will reduce the Soviet and United States strategic nuclear weapons by approximately 30 to 35 per cent - as contributing to global security and as a step towards nuclear disarmament.

10. The continued improvement in international relations, particularly between the two major Powers, the levelling off of the quantitative increases in the nuclear weapon arsenals, and the prospects for deep cuts all point to positive trends towards a less dangerous world. Although qualitative improvements in nuclear weapons continue and nuclear testing remains a contentious issue, the diminishing tension and the growing co-operation between East and West might facilitate the resolution of these issues as well. However, the possibility of the proliferation of nuclear weapons to additional States is of increasing concern. Some believe that the current political climate presents opportunities for taking steps that would minimize the chance or effect of possible untoward developments in the future.

Notes

1/ Subsequently referred to as the Group of Governmental Experts to Carry Out a Comprehensive Update of the Study on Nuclear Weapons.

2/ United Nations publication (Sales No. E.81.I.11). The study was subsequently reprinted in Nuclear Weapons. Report of the Secretary-General, Cambridge, Massachusetts, Autumn Press, 1981.

/...

CHAPTER II

EXISTING NUCLEAR WEAPONS: TECHNICAL DATA AND STATISTICS 1/

A. Introduction

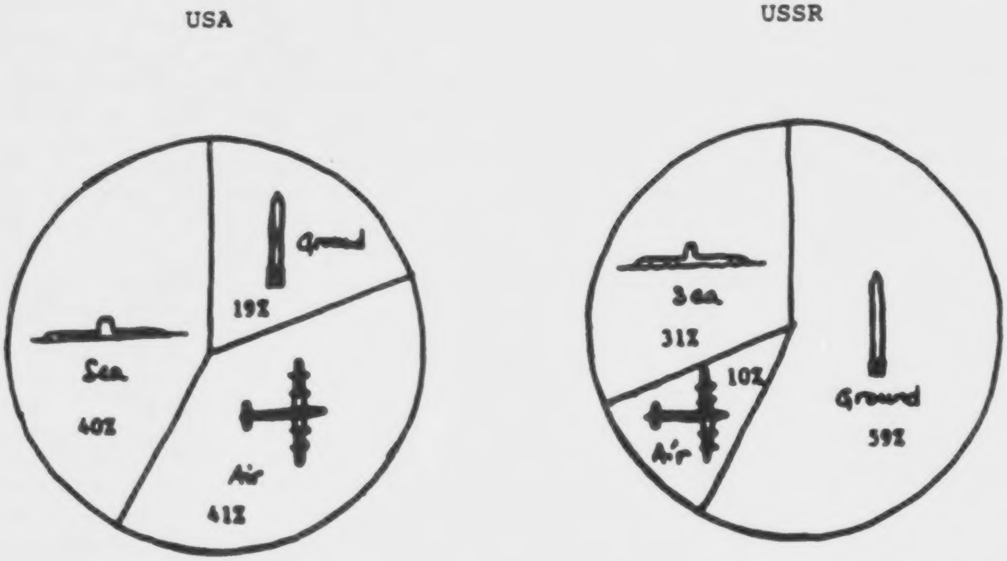
11. Nuclear weapons represent a historically new form of weaponry, which, by their multiple and far-reaching effects, provide a means of warfare whose mass destructive potential is unparalleled in human experience. Nuclear technology makes it possible to release more energy in one micro-second from a single nuclear weapon than all the energy released by conventional weapons used in all wars throughout history. In addition, nuclear weapons differ from conventional ones by the nature of their destructive effects, which comprise three elements: blast, heat and radiation. While the blast and heat are of an instantaneous nature, the radiation, which is peculiar to nuclear weapons, has both immediate and long-term effects. These effects have the potential to extend to areas beyond the borders of the target country.

12. The exact number of nuclear weapons in the world is difficult to estimate precisely. It seems that the current global total of nuclear warheads may be about 50,000, despite the elimination of some missile systems resulting from the 1987 INF Treaty between the United States and the Soviet Union. The 1980 United Nations study on nuclear weapons placed the total at that time in excess of 40,000. This would imply a significant quantitative increase. However, there are numerous indications that the 1980 estimate was too low. Consequently, the current figure of 50,000 may actually represent a decrease in the number of warheads.

13. The individual explosive yield of currently deployed nuclear warheads is estimated to span the spectrum from 100 tons to more than 1 million tons equivalent of conventional high explosive. In the 1970s and early 1980s the trend was towards deploying nuclear warheads of smaller individual yields that had a greater accuracy in their delivery. Even with this trend the aggregate explosive power of present nuclear arsenals remains in the region of 13,000 million tons of TNT, or 1 million times the explosive energy of the Hiroshima atomic bomb. 2/

14. There are five States that have officially acknowledged that they possess nuclear weapons: China, France, the Soviet Union, the United Kingdom and the United States. According to the figures given by the Stockholm International Peace Research Institute (SIPRI), the nuclear arsenals of the Soviet Union and the United States continue to contain more than 95 per cent of the total number of nuclear weapons in the world (see figure 1).

Figure 1. Estimated distribution of strategic nuclear arsenals (warheads and bombs) of the United States of America and the Union of Soviet Socialist Republics



Source: SIPRI.

B. Short description of physical properties of nuclear weapons

15. The essential part of a nuclear weapon is the nuclear explosive device or warhead. Warheads may be built into various kinds of missiles, gravity bombs, artillery shells and so on. The term "nuclear weapon" usually denotes both the nuclear warhead and the delivery vehicle that takes the warhead to the target, particularly when this vehicle is a missile. Over the years, both warheads and delivery vehicles have undergone significant processes of development and improvement (see chap. III). A "nuclear-weapon system" may include specially designed platforms, from which weapons are launched, as well as supportive systems for command, control and so on.

1. Nuclear warheads

16. There are two basic types of nuclear warheads: those based solely on fission (previously often called atomic weapons) and those which also utilize fusion (sometimes called thermonuclear or hydrogen weapons). The energy released in a nuclear explosion (yield) is usually measured in kilotons (kt) or megatons (Mt) corresponding to the energy released by a thousand or a million metric tons of the conventional explosive TNT (trinitrotoluene). 3/

17. In a fission weapon, uranium or plutonium nuclei are split into lighter fragments - fission products. If there is more than a certain minimum amount of fissile material - the critical mass - a chain reaction can be initiated. 4/ Conventional high explosives are used to bring the critical mass together very quickly to enable it to explode with great force. For a plutonium bomb the fissile material may be put together to a size that may be no larger in volume than a human fist.

18. In a fusion weapon, the nuclei of heavy hydrogen isotopes - deuterium and tritium - are fused together at very high temperatures. The fusion process is triggered by a fission explosion. The fission device is indispensable as a triggering mechanism for thermonuclear explosions. 5/

19. The energy released by a thermonuclear weapon (H-bomb) comes from both the fission "trigger" and the fusion materials. However, the amount of energy released per kilogram of nuclear explosive material can be several times as large from a fusion device as from a fission device. Extra fission energy can be added by surrounding the fusion weapons with a shell of uranium-238. The greater the proportion of fission energy released the "dirtier" the thermonuclear weapon becomes. It is called "dirty" because of the quantity of highly radioactive substances (e.g. strontium-90 and caesium-137) that are released into the atmosphere. "Cleaner" weapons have a much smaller release of these substances.

/...

2. Characteristics of nuclear warhead materials

20. All nuclear weapons contain at least a few kilograms of weapon-grade plutonium or highly enriched uranium - the fissile material. Tritium is used in all thermonuclear warheads (hydrogen bombs). Tritium, like plutonium, does not occur in nature in extractable quantities and must be created in nuclear reactors. Plutonium decays with a half-life of about 24,000 years, which means it can be stored, whereas tritium has a half-life of 12 years, and therefore requires continuous production.

21. Natural uranium is composed of two main isotopes: 0.7 per cent is uranium-235, which is a fissile isotope, and 99.3 per cent is uranium-238, which requires high neutron energies to fission. In order to create nuclear weapons, the percentage of uranium-235 present in the uranium must be increased substantially. There are many ways to increase the percentage of uranium-235, the most common being gaseous diffusion. 6/

22. The majority of nuclear weapons developed in the world today use plutonium-239 (produced by neutron irradiation of uranium-238), rather than uranium-235, as fissionable material. Plutonium-239 is easily split in a fission process. A production line for plutonium requires the capability to refine - but not necessarily to enrich - uranium, the fabrication of reactor fuel, a nuclear reactor and a chemical plant for plutonium extraction from the spent fuel elements (reprocessing). 7/

3. Delivery vehicles

23. The most important delivery vehicles for nuclear weapons are different types of rocket or jet-propelled missiles. There is, however, a variety of nuclear weapons that are designed to be delivered on targets by other means, e.g. gravity bombs, artillery shells, torpedoes and depth charges.

24. Missiles can be divided into different categories according to several criteria, such as by range, by means of propulsion, by basing mode or by notions of possible use. Long-range land-based and sea-based delivery vehicles are mainly ballistic missiles, while cruise missiles are important at somewhat shorter ranges.

25. A ballistic missile is a pilotless rocket-propelled projectile. It consists of one or more fuel stages and the final stage, which is sometimes called the warhead. The term "ballistic" derives from the motion of the final stage, which is governed by inertia and gravity after separation from the rocket.

26. Long-range missiles of this kind through vertical trajectory are capable of reaching outer space and travelling long distances before re-entering the atmosphere and reaching the target; hence the term "re-entry vehicle" (RV). The final stage may contain several nuclear warheads, which are then to be regarded as separate re-entry vehicles. In this case, the final stage is often called the "bus". The final stage may also contain various penetration aids, such as decoys (devices that resemble nuclear warheads on radar screens and are designed to confuse defences against in-coming missiles).

/...

27. Multiple RVs, which are released from the bus as soon as possible, follow separate ballistic trajectories for most of their flight paths. MRVs are not independently targeted but fall within a given diameter surrounding the target. Multiple independently targeted re-entry vehicles (MIRVs) can be independently aimed to impact upon different targets.

28. An important characteristic of ballistic missiles is the so-called throw-weight. This refers to the maximum weight of the useful load (warhead, guidance unit and penetration aids) that the missile is capable of carrying over its designated range. Thus, it serves to indicate what size of warhead, or what number of warheads of a certain size, the missile can accommodate. The ICBMs and submarine-launched ballistic missiles (SLBMs) now in service reportedly have throw-weights between about 700 and 7,500 kg. 8/

29. Aerodynamic or cruise missiles, which are propelled by jet engines, sustain their flight through the use of aerodynamic lift over most of their flight path and travel through the atmosphere parallel to the ground like an aircraft (horizontal trajectory). The most modern cruise missiles can fly below 100 metres from the ground and at a speed of up to 800 kilometres per hour (km/h). 9/ They can be guided by remote control or by on-board navigation devices. The latter enable them to dodge obstacles in their path and make their detection by radar more difficult. They have a high level of accuracy. 10/

30. Airborne nuclear-weapon systems are various types of aircraft that can carry either nuclear bombs or missiles with nuclear warheads. An aircraft carrying gravity ("free fall") bombs may be thought of as a delivery vehicle, while it is more properly denoted a "platform" when carrying missiles.

31. Delivery vehicles have different ranges. The range is a maximum distance the vehicle can travel from the launching site to the target area. It is determined by the technical capabilities of the delivery vehicle in question. The operational range under particular conditions may be less than this, depending on which military function the weapon system is designated to perform.

C. Categories of nuclear weapons

32. Nuclear weapons are assigned different military functions. There is, however, no international consensus on the way of denoting such military assignments or the corresponding weapons. In many cases, these assignments translate into technical requirements of the weapons system, with regard to such characteristics as yield, accuracy, range and means of delivery. For instance, the terms "strategic", "theatre" and "tactical" may have different connotations in different States. Some States do not accept these terms as a means of distinction between different types of nuclear weapons. Indeed, weapons called "tactical" by some might well be used in a way that is, in ordinary language, strategic as seen from the standpoint of the nation against which they are used. 11/

/...

33. The international literature mostly adheres to the categorization used between the United States and the Soviet Union in the language of certain bilateral treaties in which differentiation between strategic, theatre and tactical missiles and aircraft is made by defining their appropriate ranges. This terminology has been used in the following sections.

34. Strategic nuclear weapons are generally aimed at an opponent's overall military and economic potential and have long-range or intercontinental capability. Theatre or tactical nuclear weapons may be used against selected military targets on or behind the immediate battlefield (airbases, supply depots, reserve forces) that are related to activities at the battlefield. Consequently, they operate at much shorter ranges than strategic weapons. Weapons envisaged for use against targets in the zone of direct combat are often called battlefield weapons. As a rule they have rather short-range capability or may even be stationary.

1. Strategic

35. Strategic nuclear forces consist of land-based intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs) and strategic bombers.

36. Most ICBMs are based in fixed, hardened installations called silos. Others can be rail- or road-mobile. The ICBMs have an intercontinental range of up to 13,000 km. The flight time of an ICBM over its intercontinental range is about 30 minutes. According to official data, presently existing ICBMs carry from one to ten warheads, which may be independently targeted. 12/ ICBMs are highly accurate weapons, which is considered to make them suited for attacking hard "point" targets such as an adversary's missile silos.

37. One of the important characteristics of the SLBM force is that the system as a whole has greater invulnerability as long as the submarines are travelling undetected and are dispersed under the ocean surface. At present, no nation is known to have an anti-submarine capability that threatens this invulnerability. On the other hand, the submarines are widely considered to have a more tenuous communication link with the national command authority, particularly under wartime conditions. The SLBMs have generally been less accurate than land-based missiles and were primarily viewed as weapons to be used against larger and "softer" targets, such as military bases, airfields and possibly population centres. However, the advances in technology increasingly diminish the differences in accuracy between land-based and sea-based ballistic missiles. The SLBMs have a range of up to 12,000 km and may carry up to 14 warheads. 13/

38. The long-range strategic bombers can be used both for nuclear and non-nuclear missions. In contrast to the ballistic missiles they can also be retargeted *en route* or even recalled. This flexibility is considered a major advantage of the strategic bomber force, while its disadvantages are its vulnerability and low speed, as compared with ICBMs. The strategic bombers combat range can extend up to about 16,000 km and they can carry either gravity bombs or missiles. 14/

/...

Air-launched cruise missiles (ALCMs) can be fired from a "stand-off" position, i.e. outside the range of the opponent's air defences. If equipped with effective homing devices, air-launched missiles are considered to be effective against moving targets.

2. Tactical

39. This category of nuclear weapons can be deployed on land as well as at sea. The land-based forces include weapons such as ground mobile rockets and missiles, and air-launched bombs and missiles. Yields may vary from 1 kt or less to 1 Mt.

40. Tactical nuclear weapons deployed at sea are mounted on a variety of ships, submarines, naval aircraft and helicopters, and consist of bombs, surface-to-surface missiles (SSMs), surface-to-air missiles (SAMs) and anti-submarine warfare (ASW) rockets, torpedoes and depth charges.

41. Some of these systems with very short ranges might be denoted battlefield weapons. For use on a ground battlefield there are short range rockets and artillery shells.

42. In principle, artillery pieces of about 150 mm calibre or larger are nuclear-capable. Nuclear shells are generally believed to have yields from a fraction of a kiloton up to a few kilotons. The range of nuclear artillery is up to some tens of kilometres.

43. Atomic demolition munitions (ADMs), which are designed to be used on a battlefield, could create craters and other obstacles to an advancing enemy. These weapons do not appear to be currently deployed by nuclear-weapon States.

D. Nuclear weapon arsenals

1. Strategic arsenals

44. The composition and development of the strategic nuclear arsenals of the five nuclear-weapon States reflect these countries' military postures, which are by no means identical (see chap. IV). Nevertheless, with the exception of the United Kingdom, the common denominator between them is their reliance on the so-called triad arrangement - land-based, sea-based and bomber forces - but with different emphasis on one or the other leg of the triad. The military rationale for this arrangement lies in the differences of range, yield, accuracy, level of reliability, survivability and readiness between the various types of weapon systems.

45. A fair amount of information from governmental and academic sources is available on the strategic arsenals of the nuclear-weapon States. As a result of various bilateral disarmament negotiations between the United States and the Soviet Union, much of the official data has been publicly disclosed regarding the overall strength and the general breakdown of strategic forces of these two States.

/...

(a) The United States

46. The United States considers a triad of nuclear delivery systems a basic prerequisite for the maintenance of its defence posture. Historically, however, the United States first concentrated on manned bombers as its main means of delivery for nuclear weapons. A substantial ICBM and SLBM capacity was developed in the early to mid-1960s.

47. Concerning the land-based forces, the United States has an estimated 1,000 ICBMs with 2,450 warheads. Some 450 ICBMs are the Minuteman-II, each with a single-warhead having a yield of 1-2 Mt. The remaining 500 ICBMs are Minuteman-III with three MIRV warheads, each of either 170 or 335 kt yield. Some of the older Minuteman-III have been replaced by MX missiles. So far, 50 MXs have been deployed in upgraded Minuteman silos. The MX carries 10 MIRV warheads, each of up to about 500 kt, and has a range of over 11,000 km. 15/

48. As regards the sea-based forces, the United States has 33 submarines (SSBNs) equipped with 592 SLBMs and about 5,100 warheads. Some 208 SLBMs are Poseidon missiles with an average of 10 MIRVs, each with a yield of 40 kt. The missile has a range of 4,600 km. The Poseidon missiles were once the mainstay of the United States sea-based nuclear deterrent force, but they are now gradually being replaced by Trident-I (C-4), which has a range of some 7,400 km and is estimated to carry 8 MIRVs of 100 kt each. The United States has already deployed 384 Trident-I SLBMs on Trident SSBNs and on Poseidon SSBNs. The United States also deploys strategic sea-launched cruise missiles (SLCMs). The Tomahawk land-attack missile with a nuclear warhead (TLAM/N) has an estimated range of approximately 2,500 km and has a 5-150 kt warhead. The Tomahawk, in either the strategic/nuclear or tactical/conventional role, is intended to be installed on a large number of naval vessels of all sizes. 16/

49. The third part of the United States triad consists of approximately 350 strategic bombers with some 4,500 warheads. The bulk of the force consists of B-52s. The other major component comprises some 97 B1-B bombers.

(b) The Soviet Union

50. The Soviet Union also maintains a triad of nuclear delivery systems, but it has long chosen to emphasize the ICBM arm of its strategic triad. This was due partly to its pioneering ICBM technology and the lack of forward bases for bombers. The SLBMs were developed by the Soviet Union as a complementary, less vulnerable, retaliatory force against a possible first strike. By the 1970s, the Soviet sea-based nuclear forces had become an effective arm of the nuclear triad.

51. Currently, the Soviet Union deploys several ICBM systems, totalling 1,356 ICBMs, with approximately 6,450 warheads. Most of the missiles, i.e. some 1,100, were deployed in the period from 1966 to 1979 and consist of SS-11, SS-13, SS-17 SS-18 and SS-19. 17/ The last three carry multiple warheads. The SS-18 has a range of about 10,000 km and carries 10 warheads and the SS-19 has a range of 10,000 km with 6 warheads. The yield of both missiles is in the range of several hundred kilotons The remaining 220 ICBMs are more modern missiles. The SS-24 is a

10-warhead, rail-mobile ICBM and the SS-25 is a single-warhead road-mobile, ICBM. Both systems have ranges of over 10,000 km.

52. Concerning the sea-based forces, the Soviet Union has deployed 930 SLBM launchers of various types on SSBs and SSBNs with 3,642 warheads. Out of the total of 62 SSBNs, the Soviet Union maintains 12 Yankee-I class submarines in the Northern and Pacific fleets. 18/ They are armed with single warhead missiles. 19/ It also deploys the six largest SSBNs currently in service, the 30,000 ton Typhoon-class, each of which is armed with 20 SLBMs (SS-N-20). Only three types of the Soviet SLBMs have MIRVed warheads. 20/

53. The Soviet Navy also has a sea-launched cruise missile (SS-N-21), comparable to the United States Tomahawk, which it first deployed in 1987. It is presently deployed on submarines. 21/

54. Regarding bombers, the Soviet Union currently maintains 162 Bear and Blackjack strategic bombers. Some of the bombers are believed to have been recently fitted with cruise missiles. The new Soviet strategic bomber, the Blackjack, has a range similar to that of the United States B1-B bomber. 22/

(c) The United Kingdom

55. The United Kingdom has never simultaneously deployed a nuclear triad, although at different times it has had in service bombers, land-based and sea-based ballistic missiles.

56. During the 1950s, the United Kingdom concentrated mostly on its bomber force. By 1963, it also operated 60 United States Thor land-based missiles, which gave the British the combined capability of reaching as many as 230 possible targets. 23/ At this time, the United Kingdom had two legs of a triad: land-based medium-range missiles and bombers.

57. In 1963, the United Kingdom acquired the technology from the United States to build 4 Polaris SSBNs, each equipped with 16 single warhead SLBMs. 24/ By 1970, it had abandoned the other two legs of the triad and since then has maintained a "one-dimensional" strategic force.

58. At present, these 4 British Polaris SSBNs are each equipped with 16 missiles, carrying two warheads (MRV). Thus, the United Kingdom has in its strategic force a total of 64 SLBMs with 128 warheads. 25/

(d) France

59. France maintains a nuclear triad composed of bombers, land-based intermediate/medium-range ballistic missiles (IRBMs) and SLBMs. The French "force de dissuasion" (deterrent) is considerably smaller than that of either the United States or the Soviet Union.

60. The French nuclear bomber force consists of 20 Mirage IV with a combat radius of some 1,500 km. each with a payload of two 70 kt bombs or one 300 kt bomb. In recent years, some of these bombers have also been equipped with the ASMP

short-range attack missile with a range of 100-300 km to give them a "stand-off" capability. 26/ These missiles are intended to improve the survivability and penetration ability of the aircraft's nuclear weapons.

61. As regards the ballistic missiles, France deploys 18 IRBMs (S-3), each with one 1 Mt warhead. These have a range of 3,500 km.

62. The most important part of the French triad is its SLBMs, which presently consist of 6 SSBNs with a total of 256 warheads. Four of them are equipped with 16 SLBMs (M-20) each, which carry a single 1 Mt warhead and have a range of 3,000 km. Two submarines have been retrofitted with new SLBMs (M-4) with 6 MIRVed warheads and a range of 4,000-5,000 km.

(e) China

63. China has also adopted the triad approach to its nuclear force posture. Its strategic forces are the smallest of the five nuclear-weapon States.

64. The oldest leg of its triad are the bombers. China deploys two types of manned bombers: the IL-28 and the TU-16. Their total number is believed to be between 120 and 150 aircraft, with a range of up to 1,850 km and 5,900 km, respectively. The IL-28 is capable of carrying one 20 kt-3 Mt bomb, and the TU-16 three 20 kt-3 Mt bombs.

65. The Chinese ground-based missile force consists of approximately 150 missiles, none of which have multiple warheads. Some of them are ICBMs with a range of 13,000 km.

66. With a successful test in September 1988, China has also developed an SLBM capability. It now deploys 2 submarines with 12 SLBMs (CSS-N-3) on them. The missile has a range of 3,300 km and carries one warhead with a yield of between 200 kt and 1 Mt.

2. Tactical and battlefield arsenals

(a) Land-based

67. Following the 1987 INF Treaty between the United States and the Soviet Union, which provides for the elimination of land-based ballistic and cruise missiles of intermediate and shorter-range (5,000-500 km), only missiles of ranges less than 500 km remain in the tactical arsenals of these two nuclear-weapon States (see Chap. VIII). NATO countries (other than France) deploy 88 Lance missile launchers with warheads in the low-kiloton range in Europe. The Soviet Union deploys in Europe 1,608 short-range missile launchers, 27/ some of which have warheads in the high-kiloton range.

68. The nuclear warheads assigned to tactical and battlefield missions are kept in special storage sites on the territories of some of the United States allies in Europe and Asia. An academic source estimated the total number of United States nuclear warheads abroad assigned to land-based systems to be in the range of some

/...

6,500 in 1985. Although the great majority of these were based in the Federal Republic of Germany and in the United Kingdom, smaller numbers were deployed in Italy, Turkey, Greece, South Korea, the Netherlands and Belgium. 28/ Following the reduction or replacement of part of the European stock of warheads 29/ (pursuant to earlier NATO decisions), another unofficial source 30/ put the number of United States tactical and battlefield warheads stored in Europe in 1988 in the range of 4,600.

69. Academic sources 31/ indicate that the Soviet Union keeps tactical nuclear weapons in the German Democratic Republic, Poland, Czechoslovakia and Hungary, presumably involving a "double-key" system of control and Soviet custodianship. As at 1989, over 1,000 Soviet tactical aircraft were forward-based at military facilities in the four countries. 32/ According to the Soviet Union, with the current withdrawal of its troops from Hungary and Czechoslovakia, Soviet nuclear weapons outside its territory will remain only in the German Democratic Republic and Poland until arrangements on tactical nuclear weapons in Europe make their presence there unnecessary.

70. Some of the United Kingdom's tactical and battlefield land-based nuclear weapons are deployed in the Federal Republic of Germany.

71. France has a short range tactical nuclear force equipped with 44 Pluton ballistic missiles presumably with a 25 kt warhead and a range of about 120 km. France considers these to be pre-strategic rather than tactical weapons.

72. As regards land-based nuclear-capable aircraft, the United States forces in Europe deploy 65 medium-range bombers (FB-111A) and 300-400 forward-based strike aircraft (F-4, F-111 and others). The Soviet Union deploys 330 medium-range bombers (TU-22 Blinder and TU-22M Backfire), and also a large number of short-range strike aircraft.

73. Both the United States and the Soviet Union have developed artillery shells in the calibre range 152-240 mm and have deployed several hundreds of them in Europe. They are generally believed to have yields from a fraction of a kiloton up to a few kilotons. 33/

74. Although the United States is known to have produced atomic demolition munitions (ADMs), no peacetime emplacement of ADMs is believed to have taken place. Furthermore, all of the existing munitions of this nature are to be completely withdrawn from the United States armed forces. 34/

(b) Sea-based

75. The United States and the Soviet Union have substantial numbers of tactical nuclear weapons deployed at sea.

76. The main tactical nuclear system of the United States are its several hundred aircraft stationed on 14 carriers, which form the core of the major naval task forces. Their range is between 550 and 1,800 km. Each aircraft can carry one or two bombs with yields that reportedly vary from 20 kt to 1 Mt.

/...

77. For the purpose of anti-submarine warfare (ASW), the United States had deployed on most of the major classes of its surface vessels a number of nuclear-capable missiles with various ranges. While more detailed figures on these missiles are not available, in early 1989 reports were published to the effect that the United States Navy had decided to retire these nuclear systems, while retaining the option to introduce a new system. This retirement now seems to have taken place.

78. The United States Navy has nuclear-capable ASW aircraft and helicopters. The ASW aircraft may have a range of up to 3,800 km, and can carry one depth bomb, presumably of up to 20 kt yield. Their total number is not known.

79. The Soviet Union also deploys tactical nuclear weapons on board its fleet of vertical/short take-off and landing (V/STOL) aircraft-carriers and guided-missile cruisers. 35/

80. Other Soviet surface vessels such as cruisers, destroyers and small craft are also equipped with a variety of surface-to-surface missiles (SSMs). Their range is estimated to be from 60 to 550 km and their warhead yields are in the medium kiloton range.

81. For the purpose of ASW, the Soviet Navy deploys several hundred ASW aircraft, each of which can carry one nuclear depth bomb. In addition to these aircraft, the Soviet Union also deploys several hundred ASW nuclear-tipped missiles.

E. Systems for command and control of nuclear forces

1. General

82. To ensure that the political and military leaders of the nuclear-weapon States have access to relevant and timely information and that they remain in communication with their nuclear forces and each other, it is necessary to have an elaborate system of reconnaissance, data-processing facilities and communication networks. The two major Powers in particular have paid great attention to such systems. Some of their components are space-based sensors or communication links, others are ground-based and still others could be airborne. The totality of these assets, with their associated procedures and routines, is often referred to as "C^3I", which stands for command, control, communications and intelligence. In some cases, C^3I facilities have been hardened against nuclear attack to permit them to operate in a post-attack environment. 36/

83. The sensors include early warning satellites intended to detect missile launches and big ground-based radar stations to follow the trajectories of the missiles. The communication links include relay satellites and ground-based radio links. Most of the command centres are located in well protected underground shelters, but there are also some airborne emergency command posts. 37/

/...

2. Release procedure

84. As regards the United States, the President retains full authority over the use of nuclear weapons. If the President should become incapacitated, the Vice-President would assume responsibility.

85. The United States nuclear forces have an array of safeguards established to minimize the risk of unauthorized use. For tactical weapons a system called permissive action links (PALs) was established in the early 1960s. 38/ They use some kind of electronic locking system that guards against unauthorized use of the weapons. Some of these systems have the ability to disable or destroy a nuclear weapon in response to certain types of tampering. The control systems guard only the warhead, not the launch system. They exist both on weapons in the United States and on United States warheads attached to NATO commands in Europe.

86. The United States Strategic Air Command has an additional mechanism, a bomber coded switch system, which requires a correct code to open the aircraft's bomb bay doors. 39/

87. The United States ICBMs require two men to complete the procedure to launch. Since 1985, the command and control system for these missiles has become more robust. Every 10 missiles are controlled by a launch control centre (LCC), which passes on the unlock code. Until 1985, missile crews had physical control of the unlock codes, although they still operated under the "two-man" system. Now, all unlock codes are passed down from higher authorities. 40/

88. The procedure on United States ships, particularly SSBNs, is somewhat different. There is no PAL system. However, a large number of officers must be involved in the firing process, once authorized. In the case of SSBNs, a firing message is received and confirmed by two separate teams of men. Special keys are issued to responsible crew members and a series of "permission" switches must be engaged in the correct order to fire a weapon. The entire crew is informed of each step of the procedure. 41/

89. As in the United States, the exclusive responsibility for the use of all Soviet nuclear weapons is entrusted to the President of the Soviet Union as the Commander-in-Chief of the Soviet armed forces. In the event of the incapacitation of the Soviet President, his powers are transferred to the Chairman of the Supreme Soviet.

90. The decision for launch would be handed down from the President to the General Staff of the military. They would then communicate either to the Strategic Rocket Forces or directly to individual command posts. The only part of the Soviet military that is on a day-to-day alert are the strategic rocket forces and reportedly around 10 per cent of the SSBN force. Soviet ICBMs use a multiple-key system, similar to the one in use in the United States.

91. As is the case with United States nuclear forces in Europe, the Soviet Union retains sole control over its nuclear warheads assigned to the defence of Warsaw

/...

Treaty countries, whether those weapons are stationed in its own territory or on the territory of its allies.

92. The British nuclear command and control system in many ways parallels the procedure used in the United States. Only the Prime Minister can order the launch of the British nuclear weapons. Submarine captains also seem to have firing authority if the North Atlantic Council is silent for a predetermined period of time. The individual submarines have positive controls similar to American submarines, a two-man key system. Like the United States, the United Kingdom has no PALs on its SSBNs; rather, the message is read to the crew and two separate teams of officers confirm it. Keys are then issued by pre-launch officers to launching officers while all actions are read to the crew. The keys switch on "permission" links for launching. 42/

93. As regards French nuclear forces, all control for launching resides with the President of the Republic. The Prime Minister is next in line of succession. Like the United Kingdom and United States, the French have a two-man system for nuclear weapons use, i.e. two individuals must receive two separate codes and engage them simultaneously. 43/

94. Information on the Chinese C^3I system is almost non-existent. To keep in touch with its SSBNs, China uses very low frequency (VLF) for world-wide communications, like other navies. No information is available on the Chinese ICBMs' command and control. It would seem reasonable that China has some kind of a PAL system for its nuclear systems. It is also presumed that the Chinese Government exercises as strict control over its military command system as is the case with other nuclear-weapon States.

3. Handling of nuclear weapons

95. With a view to minimizing the risk of nuclear weapons accidents, false alarms, unauthorized launches, terrorist attacks, theft, sabotage or seizure in countries where nuclear weapons are deployed, the nuclear-weapon States have developed various safety measures for storing and handling of nuclear weapons.

96. There are a variety of technical devices on United States nuclear weapons to protect against unauthorized use, tampering and accidents (PALs, safing wires, insensitive high explosives, etc.); such devices are estimated to make the chance of an accidental nuclear explosion negligible. 44/ These precautions are also taken with United States nuclear weapons located in Europe. Nuclear weapons are stored in special "igloos", which have special protective measures, including automatic immobilization devices for intruders. 45/

97. The United States supplies almost all of the nuclear warheads assigned to NATO's defence. The custodial teams for the weapons are drawn from the United States military, who would release the weapons to authorized units, after authorization for use was received. The United States controls internal security while the host nation controls site and transportation security. 46/ These United

States custodial teams have the responsibility for control over United States nuclear weapons stored in host nations.

98. There are a number of controls on nuclear weapons at all nuclear storage sites, which are heavily guarded and hardened. Further, there are double barbed-wire fences with double locks and these are unlocked by two different people. 47/ There are many storage igloos at each site, some of which may possibly be decoys. 48/ Individual American soldiers who handle nuclear weapons have to complete the Personnel Reliability Programme and are broken up into two different types of access: "critical", which gives access to nuclear weapons for quality control, maintenance and inspections; and "controlled", which gives access to those with non-technical knowledge, or those involved in handling and assembly positions. Together, these two positions make up the two-man system and only United States citizens who have passed a rigorous security screening can occupy a "critical" position. 49/

99. British procedures for handling and storing nuclear weapons are similar to those of the United States. The United Kingdom maintains sovereignty over its nuclear weapons, but there is a high degree of co-operation with the United States in these matters.

100. Since the beginning of its military nuclear programme, France has devoted particular attention to nuclear safety and security. Since 1960, it has developed concepts, procedures and instruments to improve such safety and security. While the details of these operations are classified, according to French authorities they have produced satisfactory results.

101. According to Soviet sources, in the Soviet Union nuclear weapons are handled only by specially selected and trained officers and warrant officers. Each of them has to pass a yearly screening for reliability and competence by a commission of experts, including physicians and psychologists. On the average, from 4 to 6 per cent of those screened do not pass the tests and are not reconfirmed for the job. 50/ Furthermore, according to these sources, the Soviet Union has also introduced PALs and multiple-key systems and keeps its nuclear weapons stored in heavily fortified depots guarded by specially trained military units. Those depots are equipped with safety and warning systems reinforcing each other to prevent an unauthorized person or a group of persons from getting hold of nuclear weapons. The weapons would also automatically become inoperable if tampered with by unauthorized persons.

Notes

1/ Unless otherwise indicated, numerical data in this chapter are based on Stockholm International Peace Research Institute *SIPRI Yearbook 1990: World Armaments and Disarmament*, Oxford, Oxford Press, 1990, pp. 3-50.

2/ Comprehensive Study on Nuclear Weapons (United Nations publication, Sales No. E.81.I.11), para. 9.

/...

Notes (continued)

3/ The warhead that exploded over Hiroshima had a yield of approximately 13 kt and the one exploded over Nagasaki had a yield of 22 kt. Thomas B. Cochran, William A. Arkin and Milton M. Hoenig, Nuclear Weapons Databook: Vol. 1, United States Nuclear Forces, Cambridge: Ballinger, 1984, p. 32.

4/ This mass can range from 15-25 kg for uranium-235 and from 4-8 kg. for plutonium-239.

5/ Comprehensive Study on Nuclear Weapons, op cit., paras. 12 and 17.

6/ This so-called enrichment can be carried on to attain different concentrations of U-235 in the final product. Uranium with 3-4 per cent U-235 can fuel a commercial light water reactor. Some other types of reactors use more highly enriched uranium with 20-90 per cent U-235. The term "weapon-grade" usually denotes a U-235 content over 90 per cent. The process of atomic vapour laser isotope separation has also been examined as a possibility to eventually augment or replace the gaseous diffusion plants. Once installed, it was found to cost less per separative work unit (kg SWU) and require less energy than other enrichment techniques.

7/ Cochran et al., op. cit., pp. 23 and 24.

8/ Bernard Blake, ed., Jane's Weapons Systems 1988-1989, Surrey, Jane's Information Group Ltd., 1988, pp. 1-34.

9/ Ibid., p. 460.

10/ See Cruise Missiles: Background, Technology and Verification, Ottawa, Department of External Affairs, 1987, pp. 22-26.

11/ See Lawrence Freedman, The Evolution of Nuclear Strategy, New York, St. Martin's Press, 1981, p. 118.

12/ Frank Carlucci, US Secretary of Defense Annual Report to the Congress, Fiscal Year 1990, Washington, US Government Printing Office, 1989, p. 187.

13/ IISS Military Balance 1989-90, p. 212. Jane's Weapons Systems, 1988-1989, p. 30 for range and CEP of D-5 SLBM.

14/ Jane's All the World's Aircraft, Surrey, Jane's Information Group Ltd., 1988, pp. 368 and 369. See also Soviet Military Power, Washington, US Government Printing Office, 1989, p. 45.

15/ SIPRI Yearbook 1990 gives the yield 300 kt for the MX warhead (para. 336).

16/ Jane's Weapons Systems 1988-1989, pp. 459 and 460, provides detailed information on the vessels involved.

/...

Notes (continued)

17/ Designators for Soviet weapons used throughout the study are largely those available in Western sources, as Soviet designators have not been generally published. The correspondence between Soviet and NATO designators for Soviet missiles specified in the SALT II treaty is as follows: RS-16 = SS-17; RS-18 = SS-19; RS-20 = SS-18; RSM-50 = SS-N-18.

18/ Regarding stationing, see SIPRI Yearbook 1989, p. 14; also Soviet Military Power 1989, p. 48. Since 1980, of a total of 29, the Soviet Union has retired some 17 Yankee-I class SSBNs in accordance with the limits set out in the 1979 SALT II Agreement.

19/ Except the SS-N-6, which carries 2 MIRVed warheads. See SIPRI Yearbook 1990, p. 16.

20/ Jane's Weapons Systems 1988-1989, p. 907. For the SS-N-8, see also SIPRI Yearbook 1990, p. 16.

21/ See IISS 1989-90, pp. 6 and 30. For SS-N-21, see also Soviet Military Power 1989, pp. 47 and 76.

22/ Jane's Aircraft 1988-1989, p. 269.

23/ Lawrence Freedman, "British Nuclear Targeting", in Ball and Richelson, op. cit., pp. 116-119.

24/ Jane's Weapons Systems 1988-1989, p. 907.

25/ SIPRI Yearbook 1990, p. 20, states that only 96 warheads are actually deployed.

26/ See François Heisbourg, "British and French Nuclear Forces" in Survival, July-August 1989, p. 309. See also "Loi de Programmation Militaire", in Armée d'Aujourd'hui, No. 120, 1987, p. 45.

27/ They are referred to as Frog 7, Scud-B and SS-21. For stationing, see SIPRI Yearbook 1989, p. 22.

28/ William M. Arkin and Richard W. Fieldhouse, Nuclear Battlefields. Global Links in the Arms Race, Ballinger, Cambridge, Mass., 1985, p. 147; see also Simon Duke, United States Military Forces and Installations in Europe, Oxford University Press, 1989, p.172.

29/ Simon Duke, op cit., p. 172.

30/ Robert E. Harkavy, Bases Abroad: The Global Foreign Military Presence, SIPRI, Oxford University Press, 1989, pp. 262 and 263.

31/ Ibid.

Notes (continued)

32/ SIPRI Yearbook 1989, pp. 16-23.

33/ Harkavy, op. cit., p. 263.

34/ However, in Carlucci, op. cit., p. 151, the talk is of upgrading these systems, not retiring them.

35/ SIPRI Yearbook 1989, p. 24.

36/ Carter et al., Managing Nuclear Operations, Washington, Brookings, 1987, pp. 546 and 547.

37/ Ibid., p. 97.

38/ There are four types of PALS, designated A, B, D and F. See also Harkavy, op. cit., p. 262.

39/ Donald Cotter, "Peacetime Operations, Safety and Security" in Carter, op. cit., p. 50.

40/ Ibid., pp. 50 and 51.

41/ Ibid., p. 52.

42/ Catherine McArdle Kelleher, "NATO Nuclear Operations", in Carter, op. cit., p. 466.

43/ Ibid., p. 468.

44/ Cotter, op. cit., pp. 43-45.

45/ Ibid., pp. 52 and 53.

46/ Kelleher, op. cit., p. 452 and 453.

47/ Ibid., p. 456.

48/ Ibid., p. 455.

49/ Cotter, op. cit., pp. 60 and 61.

50/ Arguments and Facts, Moscow, No. 18, 1990.

/...

CHAPTER III

TRENDS IN THE TECHNOLOGICAL DEVELOPMENT OF NUCLEAR-WEAPON SYSTEMS

A. General

102. Nuclear weapons have undergone tremendous change and development since their inception some 45 years ago. Apart from the basic principle of nuclear reactions as the source of energy, there remains very little resemblance between the first two bombs exploded at Hiroshima and Nagasaki, which were technically very primitive, and the ballistic missiles equipped with a number of multiple independently targetable re-entry vehicles (MIRVs) in the nuclear weapon arsenals today.

103. While there is no doubt that this sophistication of nuclear weapons has been made possible by the application of modern science and technology, the role of science and technology in nuclear weapon developments has been interpreted in different ways. Thus, there are those who see the ongoing technological development of nuclear weapons as being necessitated by threats to national security and as a corollary to the evolution of theories or doctrines regarding the possible use of nuclear weapons. Newer nuclear-weapon systems usually incorporate improved command and control features and improved resistance to accidental detonation. There are also those, however, who believe that new weapon systems have sometimes emerged not because of any particular military or security consideration, but rather because technology (in conjunction with bureaucratic and other forces) may take the lead, creating weapons for which needs have to be invented and deployment theories have to be readjusted. In this connection, concern has been expressed about the extent to which scientific and technical manpower is engaged in military research and development and that such involvement leads to the production of new and more sophisticated weapons. 1/

104. An action-reaction phenomenon in arms competition among States cannot be excluded either as one influential aspect in the ongoing development of nuclear weapons. Many believe that this phenomenon reflects the interplay of expectations between the States, which results in similar systems being copied and defensive and offensive systems being designed in the expectation of new challenges from other States. In their view, the problem is exacerbated by the secrecy that surrounds the weapons research and development process in many countries, which leads to worst-case assumptions on the part of other States of the putative threat that such developments may pose. They are also concerned that the military research and development effort's own momentum and the resulting new weapons options could thus contribute to an open-ended arms competition.

B. Main features of past developments

1. Nuclear warheads

105. The first turning point in the development of warheads was the successful utilization, in the early 1950s, of fusion reactions in nuclear explosives. This

made it possible to produce thermonuclear devices capable of releasing extremely large amounts of energy. 2/

106. As a result, through the 1950s and early 1960s, the tendency was generally to build more powerful weapons, i.e. with a greater explosive yield. 3/ The fact that throughout most of the period a bomber force was the main means of delivery was an important consideration as well. This trend was also in line with the prevailing doctrinal concept at that time of the use of nuclear weapons against population centres (see chap. IV).

107. On the other hand, a development to reduce the size and weight of warheads was also initiated in the 1950s. As a consequence, it became technically feasible to produce various small nuclear charges for a variety of non-strategic uses, thus considerably expanding the potential role of nuclear weapons in a conflict situation. For instance, nuclear artillery shells were first tested in 1953. 4/

108. The technical development of nuclear warheads entailed not only reductions in their size and weight in absolute terms. It was also possible to increase their yield-to-weight ratio, particularly by the use of fusion devices. One result of this was that it became possible to put multiple warheads on strategic missiles (see chap. II).

109. For strategic warheads, the trend towards larger yields was reversed during the 1970s, especially in the United States. The fact that warheads with considerably lower yields were introduced was related mainly to significant improvements in the accuracy of the delivery systems, in particular ICBMs. The higher accuracy entails a much higher ratio between the lethality and the yield of a nuclear warhead, when employed against a small ("point") target.

110. In addition to these major developments regarding nuclear warheads, several other less known but related technological improvements were also pursued. They concerned warhead safety, reliability, versatility and hardening against adverse environments. Safety measures were aimed at minimizing both the risk of accidents in handling the weapons and the possibility of unauthorized use. For this purpose insensitive high explosives were introduced, as well as a multitude of arming and safing devices, including the PALs. Reliability of warheads was enhanced in several ways, such as by developing special materials to prevent deterioration of weapon components or special designs to withstand the tremendous acceleration in a gun tube. Versatility was enhanced by designing a warhead in such a way that different yields could be selected easily.

111. During the 40-year period from 1945 to 1985 about 100 accidents have been reported that damaged and might conceivably have caused unintended detonation of a nuclear weapon. 5/ These accidents include airplane crashes, unintended dropping of nuclear weapons from airplanes, explosions in ammunition depots or fires on board submarines. So far, however, none of those accidents has led to the unintended detonation of a nuclear weapon.

112. One way of pursuing versatility, through diversification of the nuclear inventory, is the "tailoring" of warheads to enhance or suppress various effects of

/...

the explosion. This is done by selecting different fission-to-fusion ratios to produce the desired total yield, combined with different designs of the casing and other structural components of the warhead. 6/

113. The best-known example of "tailoring" is the "enhanced radiation" weapon or the so-called "neutron bomb", a weak fusion device with a special design. Basically, it could produce much higher levels of initial neutron radiation than an ordinary fission weapon of equal yield, while at the same time suppressing the level of blast and heat, thus considerably reducing the expected damage to the surroundings. The United States developed and tested a neutron warhead but did not put it on the production line. The Soviet Union limited its efforts to a research programme. Regarding France, it has indicated that the actual state of research would allow it, if necessary, to produce a neutron weapon. 7/

114. It appears that some other technological developments related to the warhead that had been pursued by nuclear-weapon States were ultimately suspended or abandoned. For instance, it is technically possible to produce warheads with very low explosive yields (by deliberately not making full use of the fissile material). However, there were concerns that a wide deployment of such warheads, the so-called "mini-nukes", with their limited radius of material damage, would possibly lead to a "conventionalization" of their use. After some international debate, the United States, the United Kingdom and the Soviet Union declared that they would not for the time being deploy nuclear weapons with small yields in such a way as to blur the nuclear threshold. 8/

115. The 1980 United Nations study on nuclear weapons noted in connection with nuclear warhead developments that the reduction of their physical size was, in some applications, close to the limits set by the laws of physics, and that despite the research and development in the field of special types of warheads, no major breakthrough was likely to occur with regard to the basic design principles of nuclear explosives. It concluded that the evolution of delivery systems seemed likely to carry more practical importance in the future, as it had already done for some time. 9/ This conclusion still seems valid.

2. Delivery systems

116. The only nuclear warheads ever used in an armed conflict were delivered to their targets - Hiroshima and Nagasaki - in 1945 by ordinary bomber aircraft. Other forms of delivery vehicles for nuclear warheads were developed later. For instance, ground-launched ballistic missiles were first introduced in the 1950s and submarine-launched ballistic missiles around 1960. The first cruise missiles (CM) with nuclear warheads were developed in the 1950s, while longer-range CMs with sophisticated navigation aids became available much later - in the late 1970s. 10/

117. The early versions of ballistic missiles were fairly inaccurate and were thus considered to be unable to hit any targets smaller than cities or large installations (industrial, commercial or military). If the missile was intended to destroy a point target, such as one of the adversary's missile launchers, a high weapon yield would be needed to compensate for the possible deviation of the warhead from its calculated trajectory.

118. Missile accuracy is usually given in terms of the circular error probable (CEP), defined as the distance from an aiming point within which, on the average, half the shots aimed at this point will fall. Using this concept, assessments of the efficiency of various missile systems can be illustrated. For example, a 1 Mt nuclear warhead may be needed in order to destroy a particular hardened structure if the CEP of that nuclear weapon is 1 km. The same effect could result from a 125 kt warhead with a 0.5 km CEP accuracy, or a 40 kt warhead with 0.33 km CEP. Thus, increased accuracy meant that smaller yield warheads could replace high yield warheads as a threat to these types of targets. 11/

119. In other words, the nominal yield could be decreased while the effective lethality of the weapons increased. This had rather profound military effects, as it made it increasingly more difficult to protect land-based missiles from an attack, i.e. a first-strike aimed at eliminating these weapons. This required increased "hardening" of the missile silos since the existing ones no longer provided sufficient protection. This consideration, in part, bolstered further development of SLBMs, which were generally considered far less vulnerable than any type of nuclear weapons, and more recently also led to the development of mobile ICBMs. It also prompted quantitative increases of the strategic inventories.

120. It was argued by strategists that if ICBMs were left vulnerable to first-strike attacks, this could conceivably force the respective country to prepare for a possible use-them-or-lose-them scenario. Conversely, measures to decrease their vulnerability would support the deterrent posture of the respective country by enhancing its "second strike" capability. One such measure is the development of mobile ballistic missiles.

121. At the time of the preparation of the 1980 United Nations study on nuclear weapons, definite CEP values for different existing nuclear-weapon systems were not available, for reasons both of military secrecy and, presumably, insufficient basic knowledge. Also CEP values varied considerably depending on the system in question. Some of the academic sources at the time had given estimates for both United States and Soviet ICBMs as approaching a CEP of about 200 metres. Other weapon systems were generally considered less accurate, an aspect that was given a great deal of attention in subsequent years. Accuracy has improved considerably since then.

122. Another development in delivery systems was the introduction of multiple warheads on missiles. The first generation of multi-warhead systems became known as "multiple re-entry vehicles" (MRV). The missile carries several warheads (2-4), thus considerably increasing the probability of the target's destruction. The next generation, called "multiple independently targeted re-entry vehicles" (MIRV), is capable of directing each warhead against different individual targets located at varying distances up to perhaps 500 km from each other. This development has increased the effectiveness of ballistic missiles. 12/

123. The MRV warheads were deployed in the United States towards the mid-1960s on SLBMs and MIRVs around 1970 on both ICBMs and SLBMs. By the 1980s, both the United States and the Soviet Union had deployed either MRVs or MIRVs on their major weapon systems. 13/ The other three nuclear-weapon States had also been developing similar technologies, which some of them deployed in subsequent years.

/...

124. As early as around 1970, there was some discussion regarding the development of a third generation of multiple warheads, the so-called "maneouverable re-entry vehicle" (MARV) technology. The main characteristic of these warheads would be their ability to readjust their flight patterns after having re-entered the atmosphere. The main purpose of this would be to increase their probability of penetrating an ABM defence. With the aid of autonomous sensors, the MARV might also be able to attack mobile targets with a higher degree of accuracy.

125. The American and Soviet cruise missiles deployed during the 1960s (on aircraft and, by the Soviet Union, on ships) had comparatively short ranges, up to about 600 km. 14/ They were believed to be intended for use mainly against surface ships.

126. By the 1980s, the development of modern cruise missiles had gained momentum, owing to advances in propulsion and navigation technology, even though problems remained. With ranges up to at least 2,500 km and an expected accuracy of a few tens of metres, cruise missiles were envisaged to fill both a strategic role - in their air-launched version (ALCM) - and theatre roles when deployed on ships (SLCM) or on ground-mobile launchers (GLCM). 15/

127. There was also ongoing development as regards platforms for the launching of various types of missiles. By 1980, further hardening of ICBM silos was not deemed appropriate. For this reason, a great deal of attention was devoted to various schemes for ground-mobile ICBM launchers. The Soviet Union had already deployed its SS-20 medium-range ballistic missile in a mobile mode. 16/

128. The main features in the development of strategic submarines, aside from improvements of their missiles, were related to increased radius of action and more silent propulsion. More advanced navigational aids allowed increased precision in fixing the position of a submarine and hence increased accuracy of SLBMs.

129. Aircraft were modernized and modified to accommodate new types of nuclear weapons (ALCMs) or larger numbers of weapons, but no aircraft seemed to have been designed to serve solely as a nuclear weapons platform.

3. Other components

130. The other components of modern nuclear-weapon systems were also subject to various technological developments in the field. Guidance systems and some components of C^3I systems were of particular interest, even though they are too complex to be explored here in all their possible combinations.

131. Guidance systems for missiles, and for some types of mobile platforms, utilize many different techniques. 17/ To improve long-range navigation, the inertial guidance system that had long been used needed to be supplemented by intermittent, precise position information provided, for instance, by a set of satellites in geostationary orbit.

132. For homing a weapon on the target, a number of techniques are being developed, primarily for use in the conventional arms field. The essential part of these

homing systems are sensors, which include a variety of radar, infra-red and laser devices. 18/ It was believed that some of them were possible to use within strategic vehicles and others to enhance the accuracy of various tactical nuclear weapons. Any actual deployment of these technological developments was not, however, thought to have taken place before 1980.

133. Improvements in C^3I technology - which exploit the rapid advances in electronics and information and data processing - aim at increasing the reliability, survivability and speed of the systems. By 1980 additional impetus had been given to this work by some recently detected flaws in the United States C^3I system. 19/ A reliable communications system is also crucial to nuclear-war fighting. 20/

C. Main features of new developments

134. Unlike in the 1950s, 1960s and early 1970s, when major technological breakthroughs occurred in a number of important areas and took place at an accelerated speed, the technological development of nuclear-weapon systems in the 1980s has been in general less dramatic and largely focused on several specific areas as a follow-up to previous developments. Changes in emphasis on nuclear-war fighting and space-based defensive systems have also been noted.

135. In the area of nuclear warheads, technology has advanced incrementally to make warheads safer, more reliable and more flexible, i.e. capable of variable yields, possibly also requiring less fissile material to produce a given yield.

136. Apart from this, efforts are reportedly being made to improve warhead technology in several specific ways. One concerns the continued development of an earth-penetrating warhead, which could burrow deep into the ground before exploding. It would be used to hold underground targets, primarily command and control centres, at risk. Because this would place command and control itself at risk, it could be viewed as a serious development with potentially destabilizing consequences. Another effort is related to the MARV concept described above.

137. However, despite the enhanced capability that both penetration and MARVed warheads may offer, reportedly neither technology has been deployed so far on a weapon system.

138. Reportedly, the trend towards greater accuracy of ballistic missiles continues. During the 1980s, this does not seem to have been accompanied by continued lower yields of strategic warheads, however. For instance, the MX ICBM is described as carrying warheads with selectable yields of 300 or 475 kt each, as opposed to the 170 kt warheads on Minuteman-III missiles deployed in the 1970s. 21/

139. In the area of delivery vehicles, several new developments have taken place. Concerning land-based missile forces, two features are of particular military significance: the more widespread replacement of liquid fuel rockets with solid fuel and the introduction of mobile ICBMs.

/...

140. Apart from considerably diminishing the safety risks involved in handling liquid fuel, the most important aspect of the use of solid fuel is that it significantly reduces the time necessary to prepare missiles for launch, thus enhancing military preparedness of nuclear forces. Solid fuel technology was introduced in the United States in the 1960s and in the French missile forces beginning in the early 1980s. It is a more recent development in the Soviet Union where it has been implemented only for the most modern missile systems. China still uses liquid fuel for its missiles. 22/

141. Development of mobile missiles has continued and also covers the strategic area. There are currently two mobile ICBMs, the Soviet SS-24 and SS-25. Both missiles are solid-fueled. 23/ In the United States, a discussion has been under way on the possibility of developing a new single-warhead road-mobile ICBM (Midgetman), or deploying the existing MX ICBMs on railroad cars. Neither plan has yet been formally endorsed by the United States Government.

142. The major developments concerning the strategic air forces of nuclear-weapon States have been the advent of stealth technology for advanced bombers and air-launched cruise missiles.

143. Stealth technology is a combination of aircraft design, improved electronics and special material coatings designed to absorb radar waves. This technology is intended to enable aircraft and missiles to fly undetected by existing radar systems in carrying out their mission.

144. Countermeasures to stealth technology are being explored, which include various special forms of radar, such as very low-frequency, bistatic or carrier-free radar. None of these techniques is yet capable of negating stealth technology, however. 24/

145. In the United States, the B-2, or Stealth Bomber, is the most advanced aircraft to employ stealth technology. 25/ It can carry both conventional and nuclear weapons. Among the B-2 missions is destruction of mobile nuclear missiles and hardened command centres. The bomber has been developed and flight-tested, but not yet deployed.

146. The United States B-1B bomber is also a new development, in that it is a dual-capable, long-range strategic bomber capable of conforming to a multitude of roles ranging from deep-strike solo penetration of enemy territory to maritime surveillance and aerial mine-laying. These varied roles have not previously been combined into the capability of a single aircraft. Some 97 B-1B bombers have been deployed during the 1980s. 26/

147. The Soviet Union has developed the Blackjack (TU-160), a supersonic bomber for penetration missions. It also has the capability for stand-off missions, and may also possess a maritime role. The deployment of this aircraft began in the late 1980s. By the end of 1989, 17 aircraft of this type had been deployed. 27/

148. Air-launched cruise missiles (ALCMs) are designed to allow manned bombers to avoid having to face the challenge of heavy air defences while performing their

/...

mission, as they are able to launch their ALCMs before penetrating enemy air space. Thus, ALCMs effectively replace the gravity bomb and give older bombers, such as the American B-52 or the Soviet Bear, increased longevity. The sophisticated guidance system employed on ALCMs also increases the accuracy of bomber-delivered weapons.

149. Research is also under way for advanced cruise missiles (ACM) that would use stealth technology, as well as for an advanced strategic air-launched missile that would achieve supersonic speeds. Both these types of missiles would be providing maximum penetration ability against air defences. Two new cruise missiles under development in the Soviet Union reportedly employ stealth technology, the short-range attack missile (SRAM) AS-16 and the supersonic AS-X-19 ALCM. 28/ France is also developing a miniaturized independently targetable warhead, the TN-75, to be carried on a modified M-4 ballistic missile that may incorporate stealth technology. 29/

150. In the area of maritime nuclear forces, apart from continuing efforts to make nuclear submarines ever more quiet and to improve communication links with them, the two main development features of the 1980s have been the continued replacement of single-warhead and MRV missiles with MIRVed missiles, on the one hand, and the development and deployment of sea-launched cruise missiles (SLCM), on the other. There has also been a corresponding improvement in the CEP, both of the MIRVs and SLCMs.

151. Both the United States and the Soviet Union are thought to be improving their SLBM forces with regard to accuracy. Analysts have suggested that the United States Trident-II (D-5) will have a CEP of about 120 metres, similar to that of the Minuteman-II ICBM. The new Soviet SLBMs also have a higher accuracy than their predecessors. Analysts further suggest that if SLBMs have a high degree of accuracy it would make them less of a retaliatory weapon and would enhance their usefulness for counter-force strikes. 30/

152. The increased range of, inter alia, the Soviet Union's current SS-N-20 on the Typhoon submarine and the SS-N-23 on the Delta-IV allows these submarines on patrol to remain close to or within the Soviet Union's home waters. The Trident missile has a similar range. This means that the survivability of the submarines is increased, which is thought to enhance strategic stability.

153. As regards the SLCMs, their range and accuracy has considerably improved. Reportedly, the United States is deploying a new vertical launching system (VLS), which is designed to launch anti-submarine, anti-aircraft, anti-ship and land attack missiles from the same set of launching tubes. 31/

154. On the whole, it appears that the technological developments throughout the 1980s more or less followed the main trends that were evident prior to that period. Thus, no major breakthrough has yet occurred with regard to nuclear-weapon systems, although research work continues in several areas.

155. While some technological developments - in such areas as remote sensing and the use of satellites - have improved verification capabilities, the development

/...

and deployment of weapons systems incorporating advanced technologies have posed more complex problems for verification of nuclear arms limitation and disarmament agreements.

156. Considering that the Soviet Union and the United States have historically always taken the lead with regard to the technological development of nuclear weapons, it is reasonable to assume that the outcome of their negotiations on the reduction of their strategic nuclear weapons may, in many important aspects, decisively determine both the pace and trends of possible future developments in this field.

D. Ballistic missile defence systems and countermeasures

157. Parallel with technological developments in the field of nuclear weapons, at various times efforts were made by nuclear-weapon States to develop defence systems against strategic ballistic missiles carrying nuclear weapons to decrease the effectiveness of such systems.

158. Both the United States and the Soviet Union carried out research work in this field as early as the 1950s and deployed one anti-ballistic missile system each. While the United States system (which was later dismantled) was deployed for the defence of an ICBM field, the Soviet Union's Galosh system (which still exists) was built around Moscow. In 1972, by mutual agreement, the two sides limited deployment of the systems and placed various restrictions on future development and deployment of anti-ballistic missile systems (see chap. VIII). In 1974 they agreed to limit further such deployments to one site in each country, but only the Soviet Union has chosen to exercise its option under this agreement to maintain an operational ABM site.

159. For a long time it was suggested that the large phased array radar at Krasnoyarsk was intended not only for early warning of an ICBM attack, but also for ballistic missile detection and tracking. Further, the United States believed the facility could form a critical building block in a nationwide ballistic missile defence (BMD) system that the Soviet Union might have planned, and that it was in violation of the ABM Treaty. In October 1989 Soviet Foreign Minister Eduard Shevardnadze acknowledged that the Krasnoyarsk radar was in violation of the ABM Treaty and stated that it would be dismantled. 32/

160. Work on various BMD technologies continued and in the 1980s interest in the development of BMD capability was renewed in the United States. This was related, in addition to various political-strategic considerations, to the emergence of new technologies.

161. At present, research and development of strategic defence systems are progressing in a number of directions, which could lead to systems that might be used against RVs of ICBMs and SLBMs, or against the buses carrying the RVs or against the missiles themselves. 33/

162. Unlike the situation with earlier ABM weapons, which focused on interception solely during the terminal phase of an RV's flight, interest in new BMD weapons turned in the 1980s to the destruction of ICBMs and SLBMs along their entire trajectory. 34/

163. There is a whole array of existing and conceptual weapons technologies under consideration for use in BMD. System components could be either ground-, air- or space-based. There are several basic types of new BMD weapons being researched: kinetic energy weapons (KEW), lasers and particle beams.

164. In a kinetic energy weapon projectiles are hurled at high rates of speed and the force of its impact alone disables or destroys its target. The projectiles could be accelerated by non-conventional means such as electromagnetic "rail-guns". 35/

165. Another class of potential weapons are lasers, which can be sea-, air-, space- or land-based. If the laser itself is ground-based, the laser beam, theoretically, can be directed onto a target by mirrors based in space. 36/

166. Another type of potential weapon is based on the use of particle beams. These weapons would accelerate atomic or sub-atomic particles to near the speed of light. The beam would then penetrate the target and disrupt its electronics and other components. 37/ There are a number of other technologies that might be used for weapons purposes, although they remain highly theoretical. One is the X-ray laser, which would be pumped by a nuclear explosion. Another is the "plasmoid" defence, which is a cloud of energized atomic nuclei and electrons that affects warheads.

167. Possible countermeasures include shielding of ICBMs or RVs. In addition, decoy RVs can be installed in ICBMs to distract weapons or cause identification problems for tracking systems. It is also possible to shorten the boost phase of a missile by increasing its speed at launch, thus going a considerable way towards negating the ability of the other side to destroy fully loaded ICBMs before they release their RVs. 38/

168. In the 1980s, as military satellites became more integrated into military observation, communications and weapon guidance, their importance as targets also increased. Renewed focus on this field also arose as a result of a belief that a number of ballistic missile defence technologies could find an initial application as anti-satellite (ASAT) systems.

169. Both the United States and Soviet Union have carried on research, development and testing of ASATs. The Soviet Union has tested a co-orbital interceptor ASAT, while the United States has tested an air-launched direct ascent missile. 39/ The United States suspended its programme in 1988.

170. ASATs can be deployed in a variety of ways. They can be used to counter strategic defence. Many satellites would be needed to track, identify and target any incoming ICBMs. The destruction of these satellites would be devastating to nearly all types of BMD systems. ASATs could also be used to attack space-based BMD kill-mechanisms. 40/

/...

171. There has been considerable debate over the feasibility and merit of the United States strategic defense initiative (SDI) put forward in 1983. The debate has taken place not only between the United States and the Soviet Union, but also between the United States and its allies, within the United States itself, and in many other parts of the world. 41/

172. The Soviet Union has been carrying out research into technologies that could be used in a BMD system. It has, however, officially declared that it has no integrated large-scale BMD research programme, that all its BMD research is conducted within the limits of the ABM Treaty and that it has no intention to create and to deploy a nation-wide ground-based or space-based BMD. 42/

Notes

1/ See Study on the Relationship between Disarmament and Development (United Nations publication, Sales No. E.82.IX.1), paras. 403 and 407.

2/ Thomas B. Cochran, William A. Arkin and Milton M. Hoenig, Nuclear Weapons Databook: Vol. 1 (US Nuclear Forces), Cambridge, Ballinger Publishers, 1984, pp. 26-28.

3/ The first fusion device detonated by the United States in 1952 had a yield reported to be about 10 Mt. Two years later the United States tested a weapon with a 15 Mt yield, and in 1961 the USSR exploded a fusion weapon with an estimated yield of about 60 Mt.

4/ The first live nuclear artillery test was "Shot Grable", conducted in Nevada on 25 May 1953. See Cochran et al., op. cit., pp. 300 and 301.

5/ See John May, The Greenpeace Book of the Nuclear Age: The Hidden History, The Human Cost, New York, Pantheon/Greenpeace Communications Ltd., 1989, pp. 18-25.

6/ Cochran et al., op. cit., pp. 28 and 31.

7/ Ibid., pp. 28 and 29.

8/ For example, the small atomic demolition munition "effectively breaks any barrier between nuclear and conventional explosives if measured purely in terms of yield". See Guide to Nuclear Weapons 1984-85, Bradford, The School of Peace Studies, University of Bradford, 1984, p. 35.

9/ Comprehensive Study on Nuclear Weapons, paras. 76 and 85.

10/ Cochran et al., op. cit., pp. 172 and 173.

11/ Ibid., pp. 31-35.

12/ Ibid., p. 319.

/...

Notes (continued)

13/ Ibid., pp. 100-110, especially table 5.11, p. 108.

14/ See Richard K. Betts, ed., Cruise Missiles, Technology, Strategy, Politics, Washington, The Brookings Institution, 1981, pp. 32, 34, and 365-368. See also Cruise Missiles: Background, Technology and Verification, Ottawa, Department of External Affairs, 1987, pp. 28 and 29.

15/ See Cochran et al., op. cit., pp. 172-190.

16/ Sverre Lodgaard and Frank Blackaby, "The Nuclear Arms Race" in SIPRI Yearbook 1984, Philadelphia, Taylor and Francis, 1984, pp. 25-29.

17/ Here it is necessary to distinguish between ballistic missiles, which are guided mainly during the "boosting" phase, i.e. the initial part of the flight when the rocket engines work; vehicles like cruise missiles, which are driven through the entire flight path and for which guidance becomes navigation; and weapons (of any kind) in their final approach to the target, when target-acquisition and homing devices developed for conventional munitions might be used.

18/ See Jeff Hecht, Beam Weapons, New York, Plenum Press, 1984, pp. 202 and 203.

19/ See May, op. cit.

20/ War-fighting capability is an elusive term when dealing with nuclear weapons. Proponents of a war-fighting capability argue that without realistic plans to fight and win a nuclear war, deterrence posture cannot be credible. Those who maintain that there can be no winners in a nuclear war, however, see preparations for fighting one as futile and dangerous, since such planning can make nuclear war seem "winnable" and hence more acceptable. This position advocates mutually assured destruction as the basis for a credible deterrence. See Robbin Laird, The Soviet Union, the West and the Nuclear Arms Race, New York, New York University Press, 1986, pp. 58-66. See also David Robertson, op. cit., pp. 317 and 318.

21/ Cochran et al., op. cit., p. 116.

22/ Bernard Blake, ed., Jane's Weapons Systems 1988-1989, Surrey, Jane's Information Group Ltd., 1984, p. 906. See also SIPRI Yearbook 1988, p. 53.

23/ Blake, op. cit., p. 906.

24/ Jane's Defense Weekly, 23 June 1990, p. 1234; see also Flygvapennytt (Swedish Air Force News), spring 1990.

Notes (continued)

25/ The B-2 is a thick-winged "flying wing", where the wings blend into the fuselage, and radar-absorbing material coats the craft and is attached directly to the metal. See Blake, op. cit., p. 448. See also Jay M. Shafritz, Todd J. A. Shafritz and David B. Robertson, eds., The Facts on File Dictionary of Military Science, New York, Facts on File Inc., 1989, p. 434.

26/ IISS Military Balance 1989-90, p. 16. See also Frank Carlucci, US Secretary of Defense Annual Report to the Congress, Fiscal Year 1990, Washington, US Government Printing Office, 1989, table III.F.1, p. 184.

27/ SIPRI Yearbook 1990, p. 16. See also Soviet Military Power, Washington, US Government Printing Office, 1988, p. 50.

28/ SIPRI Yearbook 1989, p. 21.

29/ Ibid., p. 31. See also Commissariat à l'Energie Atomique, Rapport Annuel 1989, Paris, CEA, 1990, p. 53.

30/ See Blake, op. cit., p. 30.

31/ James P. Rubin, "Limiting SLCM's - A Better Way to START", in Arms Control Today, 1989, p. 12. See also Carlucci, op. cit., p. 145.

32/ The New York Times, p. A1, 24 October 1989.

33/ For a more detailed discussion of BMD technologies, see Stephen Weiner, "Systems and Technology", in Ashton B. Carter and David N. Schwarz, eds., Ballistic Missile Defense, Washington, The Brookings Institution, 1984, pp. 49-97.

34/ Ballistic missiles have four phases in their flight profile: (a) boost phase; (b) post-boost phase; (c) mid-course phase; and (d) terminal phase. The success of any defence would depend on which phase of a missile's flight path countermeasures were taken against it and how successful each phase of the defence was in degrading the overall level of an attack. US Department of Defense, Office of Technology Assessment, The Heritage Foundation, Anti-Missile and Anti-Satellite Technologies and Programs, SDI and ASAT, New Jersey, Noyes Publications, 1986, p. 18.

35/ Anti-Missile and Anti-Satellite Technologies and Programs, SDI and ASAT, op. cit., pp. 16 and 26.

36/ Ibid., p. 16.

37/ Ibid., pp. 127 and 128.

38/ Ibid., pp. 115-119.

Notes (continued)

39/ Satellites have a critical role in providing warning of the launch of any nuclear missile and provide indispensable links in the command and control systems in both crisis and conflict situations. For an in-depth discussion, see Paul B. Stares, "Nuclear Operations and Antisatellites", in Ashton B. Carter, John D. Steinbruner and Charles A. Zraket, eds., Managing Nuclear Operations, Washington, Brookings Institution, 1987, pp. 679-688.

40/ See "Countermeasures, Counter-Countermeasures, ad infinitum", in Hecht, op. cit., pp. 175-191.

41/ See for example Harold Brown, ed., The Strategic Defense Initiative: Shield or Snare?, Boulder, Westview Press, 1987.

42/ "Gorbachev Interviewed for United States Television", Facts on File, New York, Facts on File, Inc., December, 1987, pp. 890 and 891; see also Pravda, 2 December 1987.

/...

CHAPTER IV

DOCTRINES AND STRATEGIES CONCERNING NUCLEAR WEAPONS

A. General

173. Military doctrines are developed basically to determine the conditions under which force would be used and as guidelines for force structuring and war plans. Throughout history military doctrines have changed considerably, reflecting changes in perceptions, the evolution of the international environment and the development of different means of warfare. Similarly, various military doctrines relating to the use or threat of use of nuclear weapons have been continuously revised over the past 40 years in conjunction with the changes in the nuclear potentials of the major powers and the rapid technological developments in the field.

174. The concept of deterrence is as old as the phenomenon of war. Doctrines of deterrence basically seek to influence the decisions of the opposing side. Thus they rest on the perceptions of the State(s) being deterred. Such a State must be convinced that the other side has at its disposal the military means to support its doctrine and furthermore that there is a "sufficient" likelihood that it would implement it. Generally, deterrence is based on the threat of use of force to prevent someone from carrying out certain hostile acts.

175. In the nuclear age, however, the notion of deterrence has acquired totally new dimensions. The overwhelmingly destructive power of nuclear weapons has given new potency to the deterrence posture of the nuclear-weapon States. Nuclear deterrence by the threat of massive destruction is based on the idea that if one nuclear-weapon State launches an attack on another nuclear-weapon State, the defender will have sufficient force left after the attack in order to be able to launch a retaliatory strike that would inflict unacceptable damage on the aggressor. 1/ Thus, according to this concept, the aggressor would be dissuaded from initiating an attack. The question of nuclear deterrence takes on particular significance at the regional level with respect to those States which reportedly possess nuclear warheads or nuclear explosive devices and which, at the same time, are not parties to the Treaty on the Non-Proliferation of Nuclear Weapons. It relates also to the possibility that nuclear weapons could be used to threaten and endanger the security of a region and of neighbouring States, creating for them the need to devise appropriate security arrangements on which they can rely (see chap. III).

176. Several fundamental issues have been debated more or less since the inception of the nuclear age. One is whether nuclear weapons are indispensable for an effective deterrence. Another is whether they can deter conventional attack or only nuclear attack. 2/ Major uncertainty also surrounds critically important questions under what circumstances a certain State would in fact use its nuclear weapons. 3/ In this connection, there are those who believe that one cannot say with assurance that reality will unfold according to expectations based on the existing doctrines and that one cannot disregard the possibility of events developing independently of the professed doctrines.

177. Other issues raised are whether or not a nuclear-weapon State can credibly extend nuclear deterrence to its allies ("extended deterrence"); whether an assured retaliatory capability is sufficient for deterrence ("minimum deterrence") or if this calls for larger and more varied forces, i.e. a "war-fighting" capability; and, finally, whether deterrence in reality rests on the mere existence of powerful nuclear arsenals ("existential deterrence"). If that is the case, even quite large differences in the size of the arsenals, as well as refinements in technology and employment concepts, would be largely irrelevant. The question still remains as to how much and what type of nuclear weaponry are sufficient for deterrence. In the view of many, this has, in the past, led to an arms race resulting in excessive nuclear arsenals.

178. Different States assess nuclear weapons and deterrence differently. There are those who believe that nuclear deterrence has played an important role in preventing the outbreak of a world conflict and that nuclear deterrence will continue to be a prerequisite for international stability and world security for the foreseeable future. Others consider that the risks of a failure of deterrence are too high to be worth taking, since nuclear war could cause intolerable destruction in any part of the globe, no matter how distant from the centre of conflict. They believe that nuclear weapons should be banned and abolished and that viable security alternatives must be considered on the basis of broad multilateral co-operation rather than on a permanent adversarial relationship.

179. The views on nuclear-weapon doctrines, including deterrence, are described briefly in section D of the present chapter. More detailed discussions are presented in the United Nations Study on Deterrence. 4/ The five nuclear-weapon States have submitted, for publication in the present study, short descriptions of their doctrinal views on the use of nuclear weapons. These are given in appendix I.

180. The following section describes briefly the main features of the nuclear doctrines of the nuclear-weapon States. These doctrines have historically evolved and there has also been a fair amount of interaction between different doctrines, either through the process of negotiations on arms limitation or through changing perceptions of threats to the national security of those countries. A great deal of the evolution of and interaction between doctrines may be attributed to developments of weapon technologies.

B. Doctrines of the nuclear-weapon States

1. The United States

181. Although it was recognized in the United States during the immediate post-war years that the atomic bomb might potentially change all military strategy, no particular doctrine had emerged at that time for the use of this weapon. The bomb was viewed mainly as a somewhat bigger weapon to be used in the same way other bombs had been used. By 1948, strategic air strikes figured prominently in United States Air Force nuclear war planning. 5/

182. At the end of the 1940s and the beginning of the 1950s, under the impact of the changing world situation and the development of the Soviet Union's nuclear capability, a re-evaluation of American defence policy was begun, which affected both the level of nuclear armaments and military doctrine. The United States Strategic Air Command, which had been given overall responsibility for target planning for nuclear weapons use, recommended that, owing to the small size of the available arsenal and the paucity of reliable intelligence on Soviet infrastructure targets, counter-city nuclear strikes would be militarily more effective than attacks on the energy and transportation infrastructure. The Korean War had prompted a major US military effort and President Truman authorized an expansion of nuclear weapons production. The United States stockpile rose from 50 in mid-1948 to about 1,000 in 1953 and reached almost 18,000 by the end of the decade. 6/

183. At the doctrinal level, in 1954 the United States Secretary of State, John Foster Dulles, announced what was referred to as "the doctrine of massive retaliation". The United States, according to Dulles, reserved the option of retaliating instantly, "by means, at times, and at places of our choosing". 7/ That declaration was said to be intended primarily to underscore the preventive nature of the nuclear threat. It did not imply that the United States would automatically bomb the industrial or population centres of an adversary in the event of an attack on the United States or its allies. The United States would not necessarily have to meet military action where it occurred, but might instead respond, with or without nuclear weapons, with attacks on strategic targets.

184. The first Soviet thermonuclear test in 1953 and the launching of the first Soviet Sputnik in 1957 made it clear that the United States could be exposed to nuclear strikes. This put an end to the idea of the traditional "Fortress America" and also prompted re-evaluation of the doctrine of "massive retaliation". The question was raised: if there was to be some lower level of conflict involving the Soviet Union, should the only available United States response be all-out war, particularly when it could mean mutual suicide?

185. The need for a revised strategy was recognized by President Eisenhower and further addressed by the Kennedy Administration. Two developments took place. The first was the adoption of the single integrated operational plan (SIOP), which sought to co-ordinate nuclear planning and delivery between the various American armed services. 8/ Secondly, NATO's conventional forces were strengthened, presumably to avoid as long as possible recourse to nuclear weapons. The introduction of tactical nuclear weapons in the late 1950s and the emergence of the concept of limited nuclear warfare were two convergent factors of readjustment at the level of military doctrine.

186. The resulting NATO doctrine took the form of the concept of "flexible response". It was put forward in the beginning of the 1960s by United States Secretary of Defense Robert McNamara. "Flexible response" presumed that NATO would maintain its standing conventional forces at a level at which it could withstand attack by the Warsaw Treaty Organization until reserves were mobilized. Nuclear weapons would be used only if the West faced defeat in a conventional war. This required the existence of flexible and effective conventional forces, if necessary supported by tactical nuclear weapons and ultimately by strategic forces. The

/...

doctrine stated that each case of aggression would be dealt with independently and American nuclear response could be controlled for varying levels of response to aggression. 9/

187. A retaliatory response could be as small as one tactical nuclear charge or as large as a multi-target strike on the Soviet Union. Thus, the Soviet Union would be deterred from attacking since a conflict would run the risk of escalating to an all-out nuclear war. 10/ The United States would deploy its nuclear forces in a structure and in sufficient numbers to enable it to ride out a possible first strike by the Soviet Union and then retaliate with enough nuclear forces to destroy one fifth to one fourth of the Soviet population and one half to two thirds of the Soviet industry ("assured destruction"). 11/ Secretary of Defense McNamara also initially proposed a counter-force strategy. A counter-force attack is an attack aimed at an adversary's military capability, especially its nuclear forces; a counter-value attack is directed against an opponent's civilian and economic centres. However, the technically feasible options of the time offered limited possibilities of reaching and concentrating on military targets. With further technological developments this option gained in importance.

188. The problem of developing credible options was again elaborated by the Nixon Administration, which sought to create a set of "limited nuclear options" and thus enhance in-conflict escalation control. According to some sources, in 1974 a plan was outlined for the employment of nuclear weapons in a way that would allow the United States to "conduct selected nuclear operations". 12/ This approach was reportedly reconfirmed and further developed by the Carter Administration, although Secretary of Defense Harold Brown stressed that "assured destruction" continued to form the "bedrock" of nuclear deterrence. 13/ The improvements in the accuracy of missiles and in command and control facilities during the past two decades have stimulated interest in the concept of "selected nuclear operations" and nuclear war-fighting.

189. In 1982, the States parties to the North Atlantic Treaty reaffirmed in a Declaration that none of their weapons, nuclear or conventional, would ever be used except in response to attack. 14/

190. Perhaps the most significant doctrinal development in the 1980s was the United States' initiative for developing a system of strategic defence (SDI). Basically, the proponents of the idea are endeavouring to deter aggression by denying a potential adversary the certainty that his nuclear strike would succeed. They believe that deterrence would thus become more defensive and less nuclear. 15/

2. The Soviet Union

191. After the Second World War, although the Soviet Union was aware of the potential of nuclear weapons, this did not seem to have much effect on its military doctrine. Nuclear weapons were treated simply as bigger explosives.

192. In 1960, the Chairman of the Soviet Council of Ministers, Nikita Khrushchev, announced that a new branch of the Soviet military forces had been formed - the strategic rocket forces. He also announced that the conventional forces would be

reduced or replaced, because nuclear weapons "had made it possible to raise our country's defensive power to such a level that we are capable of making further reduction of our military forces". 16/

193. In 1961 Defence Minister Malinovsky stated that one of the most important points of the Soviet military doctrine was that a world war - if initiated by an aggressor - "inevitably would take the form of a nuclear missile war". 17/ This was an indication that the concepts of deterrence and massive retaliation began to play an important role in Soviet thinking at the time.

194. These and other statements were followed in 1962 by the publication in the Soviet Union of a comprehensive work on military strategy edited by Marshal V. D. Sokolovsky, which recognized the revolutionary impact of the appearance of nuclear weapons on military strategy. One central thesis in this work was that a war where the two major Powers were involved would inevitably escalate to a general nuclear war:

> "It should be emphasized that, with the international relations existing under present-day conditions and the present level of development of military equipment, any armed conflict will inevitably escalate into a general nuclear war if the nuclear Powers are drawn into this conflict." 18/

Based on this assumption, the Soviet Union attempted in parallel to build up its strategic nuclear forces creating an ability, if necessary, to deliver a credible strike in case of war.

195. When the concept of "flexible response" was adopted by NATO in 1967, the Soviet views on total nuclear war also started to change gradually. Nuclear weapons were still depicted as a decisive element of war, but it was maintained that only with conventional combined arms operations could the war be won. Beginning in 1965-1966, the Soviet Union apparently began to consider that nuclear war could remain geographically limited. The new edition of Marshal Sokolovsky's work on military strategy supported an increasingly flexible view of the use of nuclear weapons, thus indicating possibilities other than simply massive strategic retaliation:

> "In working out the forms and methods for conducting a future war, an entire number of questions should be considered: how will the war be unleashed, what character will it assume, who will be the main enemy, will nuclear weapons be employed at the very start of the war or in the course of the war, which nuclear weapons - strategic or only operational-tactical - where, in what area or in what theatre will the main events unfold, etc." 19/

196. Eventually, Soviet doctrine underwent further changes. It subsequently held that a war would not inevitably become nuclear. Thus, the Soviet military writer Colonel-General A. S. Zjoltov wrote in 1972 that "it is completely possible that a war can be conducted with only conventional weapons". 20/ He said that war without nuclear weapons was possible; even if nuclear weapons were used, these weapons could not solve all military tasks; the use of nuclear weapons against some targets might prove not operative; nuclear weapons could under some circumstances be an

obstacle for the advancement of a country's own forces; and that many conventional weapons could be used with great effect against the nuclear weapons of an enemy.

197. In 1976, it was stated on the highest level in the Soviet Union that "if all presently accumulated nuclear stockpiles were used, humanity would be totally destroyed". 21/ In 1981, the Soviet Union announced that victory in nuclear war would be impossible, a sentiment it has expressed ever since. In 1982, the Soviet Union officially declared that it would not be the first to use nuclear weapons in any conflict. It stated that it would not seek to use nuclear weapons since any use, no matter how limited, could lead to escalation to all-out nuclear war. Nevertheless, the Soviet Union continued the expansion of its strategic nuclear forces, which, according to the Soviet Union, took into account the need to ensure their survivability.

198. The Declaration adopted in 1987 by the Soviet Union and other States parties to the Warsaw Treaty Organization envisaged a new alliance military doctrine subordinated to the task of preventing war, whether nuclear or conventional. Military means to resolve any disputes were said to be inadmissible in the nuclear age. The Declaration pointed out that the defensive nature of their military doctrine resided in the undertakings of the Warsaw Treaty States that they: (a) would never, under any circumstances, initiate military action unless they were themselves the target of an armed attack; (b) would not be the first to use nuclear weapons; (c) did not have any territorial claims to any other State; and (d) did not view any State or any people as their enemy. 22/

199. Despite the significant improvements in the international situation and in Soviet-American relations, the Soviet Union considers that it has to take into account in its defence structure, including its strategic arms structure, the considerable military potential of the United States and NATO. For the strategic nuclear forces of the Soviet Union, the essence of defence sufficiency is determined by the need to maintain those forces in such quantity and quality as to provide reliable retaliation capability against nuclear attack upon it in any circumstances, even the most unfavourable. The Soviet Union maintains that it does not seek military supremacy over the United States and does not lay claim to greater security, but at the same time it is fully resolved not to allow the latter to gain military supremacy over it.

200. The Soviet Union believes that the strategic balance that has developed between the nuclear forces of the USSR and those of the United States, both in the overall quantity of strategic nuclear weapons and in their real operational potential, makes possible in any circumstances to inflict unacceptable damage on the aggressor in a retaliatory (second) strike. The Soviet Union has stated that it is in favour of curbing the nuclear arms race through the contractual lowering of the levels of nuclear weapons. In reducing strategic nuclear weapons, emphasis should be placed on enhancing strategic stability through strengthening their invulnerability while reducing their overall quantity and thus retaining these weapons as effective means of retaliation but not of attack (first strike).

3. The United Kingdom

201. The United Kingdom remains fully integrated in NATO. As a member of NATO, the United Kingdom is covered by the United States' extended deterrence. Even though the United Kingdom's nuclear forces are committed to NATO's policy of flexible response, the United Kingdom's possession of its own nuclear weapons gives it an option to initiate independently a nuclear response to attack. These two roles would complicate the strategic responses of a potential aggressor.

202. Although the United Kingdom's Lance tactical nuclear missiles are under a dual-key system with the United States, its other forces are controlled by the United Kingdom alone. British nuclear weapons are deployed both on British soil and in the Federal Republic of Germany. 23/ During a European conflict and where British nuclear weapons were to be used as part of NATO forces, the Supreme Allied Commander in Europe, an American, needs British approval to order the use of British nuclear weapons. 24/

203. British strategic doctrine is based on what is commonly known as minimum deterrence. In view of the relatively limited number of strategic warheads at its disposal, at present some 128, the doctrine is presumed to be almost purely counter-value. 25/

204. Most of Britain's forces are targeted on the Soviet Union. In 1962 Britain dedicated its Polaris force to NATO as a strategic deterrent to publicly underline the focus of its nuclear forces. 26/ The United Kingdom's strategic nuclear forces ensure that it could "inflict a blow so destructive that the penalty for aggression would have proved too high". 27/

4. France

205. Along with the process of withdrawing its military forces from NATO control in 1966, France was developing the essentials of its autonomous national doctrine of nuclear deterrence. France maintains an independent nuclear force, since it believes such a force to be essential for its defence and independence.

206. France's nuclear strategy is one of *dissuasion du faible au fort*, or the weak deterring the strong. Deterrence and security rest on the threat of nuclear retaliation against a conventional or nuclear attack on France.

207. According to French declarations, if France felt its vital interests were threatened, it would launch a nuclear "last warning" toward the attacking State. Should the aggressor persist in his actions, this shot would be the precursor of a devastating nuclear attack against France's opponent. Since France's nuclear doctrine is well publicized, the purpose of the ultimate warning would be that the attacker could then determine that the benefits gained by pursuing the attack on France would be far inferior to the costs incurred by doing so. 28/

208. Originally French nuclear strategy was defined as being aimed at defending French territory. Subsequently, France indicated that it was aimed at defending the vital interests of France. France stresses that the decision to use its nuclear weapons can, by definition, only be made on the sole basis of its national sovereignty. To fulfil its nuclear strategy, the French triad ensures a survivable second-strike capability that is seen as reducing the likelihood of a pre-emptive strike against France. 29/

5. China

209. When China first acquired a nuclear-weapon capability, it announced that China would never be the first to use nuclear weapons, and would not, in any circumstances, use nuclear weapons against a non-nuclear-weapon State. 30/ However, China's nuclear weapons employment strategy remains largely unknown.

210. China's defence policy was based for many years on the concept of a "people's war" on the one hand and nuclear deterrence on the other. In the 1960s the people's war concept dominated. According to Mao Zedong, an attack on China, whether nuclear or conventional, would have to be followed by an invasion of ground forces, and this is where the supremacy of the concept of the people's war would be felt. Hostile forces would be lured deep into China's territory, "bogged down in endless battles and drowned in a hostile human sea". 31/

211. As a result, the Chinese seemed to have opted for a minimal nuclear deterrent. In addition, in spite of a renewed emphasis on its regular military forces, China continued to promote the idea of "peasant armies", which, owing to their size and dispersal, could not be wiped out by nuclear attacks. The Chinese force structure supporting its nuclear doctrine, however, was reported to be pragmatic and flexible. 32/

212. During the last years of the 1970s, it seemed that the adherents of the concept that in war men are more important than weapons had lost ground. Furthermore, there were indications that efforts were under way to develop more modern general-purpose forces in order to meet more limited military contingencies than the extremes of nuclear deterrence or mass war. There were also indications that China was interested in developing tactical nuclear weapons. 33/

213. It appears that currently in China, the modernization of existing nuclear-weapon systems takes precedence over a dramatic quantitative build-up of nuclear forces. 34/

C. Relationship between nuclear weapons, non-nuclear weapons and deterrence

214. The relationship between nuclear and non-nuclear weapons and its impact on military doctrines is crucial to an examination of the concept of deterrence.

215. The discussion regarding this relationship has centred chiefly on the situation prevailing in Europe where the two military alliances, NATO and the Warsaw Treaty Organization, have over the years faced one another with a large concentration of forces, both nuclear and conventional. Notwithstanding this concentration on Europe, similar points could be drawn in relation to the Sino-Soviet nuclear balance and indeed to maritime strategy in the Pacific.

216. On the NATO side, the perceived superiority of the Soviet Union and the Warsaw Treaty countries with regard to conventional forces has long been a focal point of a debate on the overall balance of forces, including the role of nuclear weapons in the maintenance of a credible deterrent posture in Europe. The doctrine of flexible response presupposes the existence of conventional forces sufficiently strong to provide the NATO alliance with options other than those of defeat or an early nuclear response. At the same time, NATO has considered it necessary to retain the possibility of a first use of nuclear weapons at least as long as the perceived conventional imbalance has not been rectified and the other side possesses large and flexible nuclear forces. In a policy declaration, the North Atlantic Council Meeting held at Brussels in May 1989 stated in its communiqué that "the Allies' sub-strategic nuclear forces are not meant to compensate for conventional imbalances". 35/ In June 1990, NATO foreign ministers stated that "for the foreseeable future, the prevention of war will require an appropriate mix of survivable and effective conventional and nuclear forces at the lowest levels consistent with our security needs". 36/

217. The debate on the need to further reduce incentives for the early use of nuclear weapons in a major war in Europe has continued during the 1980s. In 1979 the United States decided to reduce its stockpile of tactical nuclear weapons in Europe. At the NATO meeting at Montebello in 1983, decisions were taken on the further restructuring of NATO's forces, including an agreement to withdraw a total of 1,400 tactical nuclear warheads from existing stockpiles. 37/

218. The Soviet Union holds that its military doctrine has traditionally stressed the importance of both non-nuclear and nuclear weapons as elements of an effective military posture. Over the years, the emphasis of these components has varied, reflecting the evolution in the Soviet overall concept of military strategy as well as its perceptions of the threats to its national security. This pertains to the European theatre in particular, which throughout the post-war period has remained the primary theatre of operations in Soviet military planning. In recent times, Soviet military doctrine has elaborated a new approach towards determining the strength of armed forces, their structure and military construction as a whole that is being put into effect. The Soviet Union has stated that in dealing with these issues it proceeds from the principle of reasonable sufficiency for defence. 38/

219. With regard to strategic offensive weapons, this principle, according to the Soviet Union, requires maintenance of the approximate balance in such weapons between the Soviet Union and the United States. Their structure may differ, but their potential combat capability at any level of reductions should be comparable.

220. The Soviet position is that, for conventional armed forces, sufficiency for defence implies a level of battle strength at which they are capable of repelling

possible aggression, but, at the same time, not capable of carrying out an attack and conducting large-scale offensive operations. This means giving armed forces a non-offensive structure; limiting the number of strike-weapon systems; changing the groupings of armed forces and their deployment, with the aim of enhancing their capabilities for defence; and lowering the levels of military production, military expenditure and military activities as a whole.

221. The Soviet Union has announced that the structure of its Armed Forces is being reorganized in a defensive spirit, as follows. Apart from unilateral reductions in its Armed Forces by 500,000 men (to be completed by the end of 1990) the number of military regions, armies and general military divisions has been reduced. The correlation between means of offence and means of defence is being changed in favour of the latter. Operational manoeuvre groups and concentrated tank groupings have been disbanded. Those Soviet divisions still remaining for the present in the territories of the allies of the Soviet Union are being reorganized. 39/ A large number of tanks are being withdrawn from these divisions (40 per cent of those in the motorized infantry divisions and 20 per cent of those in the tank divisions) and taken out of service. The divisions are being given a defensive structure. 40/

222. Following the unilateral withdrawal of some 500 tactical nuclear weapons from Europe in 1989, the Soviet Union announced that it was willing to make further significant reductions of its tactical nuclear missiles as soon as the NATO countries would formally agree to start negotiations on tactical nuclear weapons in Europe. It also reiterated its proposals to include the issue of short-range nuclear forces in the agenda on disarmament and arms reduction in Europe. In April 1990, NATO agreed to start negotiations on tactical nuclear weapons after the conclusion of an agreement on conventional force reductions in Europe (CFE).

223. The progress in the CFE negotiations at Vienna, the Soviet conventional force reductions, the restructuring of Soviet and other Warsaw Treaty country forces in a more defensive direction, following the adoption in 1987 of a new military doctrine of the Alliance, as well as the withdrawal of some United States tactical nuclear warheads from Europe, are developments with potentially far-reaching implications for traditional force postures in Europe.

224. The highest representatives of the Warsaw Pact member States, gathered in Moscow on 7 June 1990 for a meeting of the political consultative committee, stated, *inter alia*: "Participants in the meeting are unanimous in their opinion that the ideological enemy image has been overcome by mutual efforts of the East and the West". They further stated: "Confrontation elements contained in documents of the Warsaw Treaty and the North Atlantic Treaty Organization that were adopted in the past are no longer in line with the spirit of the time" (see A/45/312, annex).

225. At the July 1990 North Atlantic Council meeting of Heads of State and Government, a Declaration was adopted in which it was stated, *inter alia*, that the Alliance "will never in any circumstances be the first to use force". Furthermore, the Declaration stated the following: 41/

"The political and military changes in Europe, and the prospects of further changes, now allow the Allies concerned to go further. They will thus modify the size and adapt the tasks of their nuclear deterrent forces. They have concluded that, as a result of the new political and military conditions in Europe, there will be a significantly reduced role for sub-strategic nuclear systems of the shortest range. They have decided specifically that, once negotiations begin on short-range nuclear forces, the Alliance will propose, in return for reciprocal action by the Soviet Union, the elimination of all its nuclear artillery shells from Europe.

"New negotiations between the United States and the Soviet Union on the reduction of short-range nuclear forces should begin shortly after a CFE agreement is signed. The Allies concerned will develop an arms control framework for these negotiations which takes into account our requirements for far fewer nuclear weapons, and the diminished need for sub-strategic nuclear systems of the shortest range.

"Finally, with the total withdrawal of Soviet stationed forces and the implementation of a CFE agreement, the Allies concerned can reduce their reliance on nuclear weapons. These will continue to fulfil an essential role in the overall strategy of the Alliance to prevent war by ensuring that there are no circumstances in which nuclear retaliation in response to military action might be discounted. However, in the transformed Europe, they will be able to adopt a new NATO strategy making nuclear forces truly weapons of last resort.

"We approve the mandate given in Turnberry to the North Atlantic Council in Permanent Session to oversee the ongoing work on the adaptation of the Alliance to the new circumstances. It should report its conclusion as soon as possible.

"In the context of these revised plans for defence and arms control, and with the advice of NATO Military Authorities and all member States concerned, NATO will prepare a new Allied military strategy moving away from 'forward defence', where appropriate, towards a reduced forward presence and modifying 'flexible response' to reflect a reduced reliance on nuclear weapons. In that connection, NATO will elaborate new force plans consistent with the revolutionary changes in Europe. NATO will also provide a forum for Allied consultation on the upcoming negotiations on short-range nuclear forces."

D. Differing positions regarding nuclear deterrence

226. Depending on the attitude regarding nuclear weapons and the role of these weapons in international relations, schools of thought on the subject range from acceptance by necessity to total rejection of nuclear weapons (see United Nations Study on Deterrence).

227. Proponents of deterrence maintain that deterrence is not just a western position but a universal concept. They believe that the success of nuclear

deterrence is a political and strategic fact of the post-war period. It has been deemed necessary for constraining the offensive use of military forces and for resisting possible military and political intimidation by a potential opponent. Thus, in their opinion, nuclear deterrence is an exclusively defensive strategy and represents the best means of maintaining stability. 42/

228. The existence of nuclear deterrence, they believe, has not only preserved the European continent from an East-West armed conflict, but has also led to a historic break with the process of confrontation, which frequently gave rise to armed conflicts. In their opinion, no system of security has been able up to now to offer guarantees similar to those provided by nuclear deterrence. They maintain that deterrence is also fully compatible with the principle of self-defence recognized by the Charter of the United Nations. 43/

229. Furthermore, they also believe that conventional warfare, which since the Second World War has decimated populations in many parts of the world with increasingly destructive weapons, is no more moral than nuclear non-warfare. Consequently, nuclear deterrence cannot be judged in moral or ethical terms without taking into account what they consider the most relevant criterion in this respect, that of stability: past, present and future. The world is no less secure today than in 1914 or 1939 when nuclear weapons were unknown. 44/

230. The critics of nuclear deterrence point out that nuclear weapons are weapons of mass destruction radically different from any other weapons mankind has previously known. They are weapons that defy traditional concepts of strategy. Any nuclear-weapon State that relies on nuclear deterrence, they believe, must ultimately be prepared to employ its weapons. They contend that military response, according to international law, must not be out of proportion with an armed attack. The use of nuclear weapons in response to a conventional attack would be, however, inherently a disproportionate response. Furthermore, their use would entail a risk of escalation to an all-out nuclear war, which would mean not only the total destruction of combatants, but also a threat to the survival of non-nuclear-weapon States and, in the end, of all mankind. The order of damage likely in a nuclear conflict would be beyond all historical experience. 45/ The overwhelming majority of non-nuclear-weapon States have rejected nuclear weapons and related doctrines as a means for their security.

231. A basic conceptual difficulty associated with the doctrine of nuclear deterrence in the opinion of its critics is that it continues to expound the utility of the possession of nuclear weapons and their possible use. Since all States have equal rights to security, such an approach, they argue, runs counter to desired objectives of nuclear non-proliferation, particularly in an environment of improved international relations. In addition, critics argue that it is not possible to prove that nuclear deterrence is to be credited with the maintenance of peace in Europe. In any case, the risk of nuclear war is unacceptable to them (see chap. VII). Furthermore, they believe that in some cases the possession of nuclear weapons complicates the solution of international problems, particularly at the regional level. A country that possesses nuclear weapons and is not a party to the Non-Proliferation Treaty will rely on such weapons, for purposes of intimidation or if necessary for use, as long as regional problems remain unsolved, and it will do

/...

so in its dealings with parties that do not have nuclear capabilities for warlike purposes. In such a case, nuclear deterrence thus becomes a significant factor militating against the integrity of certain regions.

232. Other criticisms include the issue of rationality. Critics contend that misperception of the other side's motives, miscalculation or even accidental launch of weaponry could remove weapons from rational control.

Notes

1/ The concept of unacceptable damage was introduced by United States Secretary of Defense Robert McNamara in the 1960s and defined as destruction of 20 per cent of the Soviet population and 50 per cent of industrial capacity. Subsequently many theorists have contended that the destruction by a nuclear strike on even a few major cities would constitute "unacceptable damage" for that country. There is no precise method of measuring levels of destruction to include the effects of fall-out, general social disruption, etc. Lawrence Freedman, The Evolution of Nuclear Strategy, New York, St. Martin's Press, 1989, pp. 246 and 247.

2/ Study on Deterrence (United Nations publication, Sales No. E.87.IX.2).

3/ See David Robertson, Dictionary of Modern Defense and Strategy, London, Europa Publications Ltd., 1987, pp. 133 and 134.

4/ See Study on Deterrence, op. cit.

5/ David Alan Rosenberg, "The Origins of Overkill: Nuclear Weapons in American Strategy 1945-60", in Steven E. Miller, ed., Strategy and Nuclear Deterrence, Princeton, Princeton University Press, 1984, pp. 124-127.

6/ Ibid., pp. 124-133.

7/ John Foster Dulles, "The Evolution of Foreign Policy", in The Department of State Bulletin, Vol. 30, 25 January 1954, p. 108.

8/ The first SIOP, formally designated SIOP-62, was completed in December 1960 and officially entered into effect on 1 July 1961 (i.e. the beginning of fiscal year 1962). Since then there have been SIOP-63 (in 1962), SIOP-5 (in 1976) and SIOP-6 (in 1983).

9/ See Robin Laird, The Soviet Union, the West and the Nuclear Arms Race, New York, New York University Press, 1986, p. 49. See also Alexander L. George and Richard Smoke, eds., Deterrence in American Foreign Policy, New York, Columbia University Press, 1974, pp. 31 and 32.

Notes (continued)

10/ A ladder of escalation is used to describe the course that a crisis would take as it proceeded from the lowest levels of conflict (diplomacy and sanctions) to all-out nuclear war and mutual annihilation. Depending on the seriousness of the situation, a State may respond to an attack with what it regards as appropriate means, which may be conventional weapons, tactical nuclear weapons or various modes of employment of strategic nuclear weapons.

11/ Desmond Ball, "The Development of the SIOP, 1960-1983", in Strategic Nuclear Targeting, Desmond Ball and Jeffrey Richelson, eds., Ithaca, Cornell University Press, 1986, p. 69.

12/ See Laird, op. cit., pp. 58-64.

13/ Desmond Ball, op. cit., pp. 76-79. See also Committee on Foreign Relations, Nuclear War Strategy: Hearing Before the Committee on Foreign Relations, US Senate, 96th Congress, 2nd session, on Presidential Directive 59, 16 September 1980, Washington, US Government Printing Office, 1981.

14/ NATO Review, Vol. 30, No. 3, 1982, pp. 25-27.

15/ See, for example, Paul Nitze, "On the Road to a More Stable Peace?", in P. Edward Haley and Jack Merritt, eds., Strategic Defense Initiative, Folly or Future?, Boulder, Westview Press, 1986, pp. 37-41.

16/ Pravda, 15 January 1960.

17/ Pravda, 25 October 1961.

18/ V. D. Sokolovsky, Soviet Military Strategy (English translation), MacDonald and Jane's, London, 1975, p. 195.

19/ Ibid., p. 288.

20/ A. S. Zjoltov, Militärische Theorie und Militärische Praxis, Berlin, 1972.

21/ From a speech of Leonid Brezhnev in Bucharest, Pravda, 25 November 1976.

22/ See document A/42/313-S/18888.

23/ Peter Malone, The British Nuclear Deterrent, New York, St. Martin's Press, 1984), pp. 92 and 94.

24/ Ibid., pp. 93-95.

25/ SIPRI Yearbook 1990, Oxford University Press, p. 20.

26/ Malone, op. cit., p. 93.

/...

Notes (continued)

27/ Ministry of Defence, The Future United Kingdom Strategic Nuclear Deterrence Force, Defence Open Government Document 80/23, London, HMSO, 1980, p. 5.

28/ David Yost, "French Nuclear Targeting", in Desmond Ball and Jeffrey Richelson, eds., Strategic Nuclear Targeting, Ithaca, Cornell Studies in Security Affairs, Ithaca, 1986, p. 134.

29/ Ibid., p. 106.

30/ George Segal, "Nuclear Forces", in George Segal and William T. Tow, eds., Chinese Defense Policy, Urbana, University of Illinois Press, 1984, p. 99.

31/ Ralph L. Powell, "Maoist Military Doctrine", in Asian Survey, April 1968.

32/ Segal, op. cit., pp. 100-109.

33/ Ibid., p. 106.

34/ Economic reforms emphasizing the civilian sector and improved relations with the USSR may have led to a decrease in China's pursuit of quantitative improvements in its nuclear weapons programmes. See SIPRI Yearbook 1988, p. 52. See also SIPRI Yearbook 1989, p. 34.

35/ "A Comprehensive Concept of Arms Control and Disarmament", adopted by Heads of State and Government at the meeting of the North Atlantic Council at Brussels on 29 and 30 May 1989 (A/44/481, annex II).

36/ See Conference on Disarmament document CD/1006, para. 11.

37/ Ivo Daadler, "NATO Nuclear Targeting and the INF Treaty", in Journal of Strategic Studies, Vol. 11, September 1988, p. 279.

38/ See "On the military doctrine of the Soviet Union", statement of the Chief of General Staff of the Armed Forces of the USSR General of the Army, M. A. Moiseev, at the Vienna seminar of 35 States on military doctrines, 16 January 1990.

39/ By 1991 all Soviet troops are to be withdrawn from Hungary and most likely Czechoslovakia as well. The future of Soviet troops on East German soil remains to be seen, but it appears certain that they will undergo reductions from their present level of approximately 380,000 troops.

40/ See SIPRI Yearbook 1989, "The Soviet Military and Perestroika", pp. 24 and 25.

41/ See Conference on Disarmament document CD/1013, paras. 16-20.

Notes (continued)

42/ See, *inter alia*, Christopher Achen and Duncan Snidal, "Rational Deterrence Theory and Comparative Case Studies", in *World Politics*, Vol. 41, January 1989, pp. 143-169.

43/ See Amos J. Peaslee, *International Governmental Organizations Constitutional Documents*, Part One, The Hague, Martinus Nühoff, 1974, pp. 1310 and 1311.

44/ See, *inter alia*, Bernard Brodie, "The Development of Nuclear Strategy", in Miller, *op. cit.*, p. 14.

45/ See Julio Carasales, "Chapter I", *Study on Deterrence* (United Nations publication, Sales No. E.87.IX.2).

CHAPTER V

DEVELOPMENT, PRODUCTION AND TESTING OF NUCLEAR WEAPONS

A. Decision-making regarding the development and testing of nuclear weapons

233. The international community is divided on the issue of the possession of nuclear weapons. The overwhelming majority of States have refrained from acquiring such weapons. More than 45 years after the first nuclear devices were developed, only a small number of States have acquired nuclear arms. Significantly, more than 130 States, including three nuclear-weapon States, in the Final Declaration of the 1985 Third Review Conference of the Non-Proliferation Treaty, declared their continued support for the prevention of proliferation of nuclear weapons or other nuclear explosive devices. 1/ It appears, therefore, that the vast majority of States believes that acquisition of nuclear weapons would not serve their security interests and that emergence of additional nuclear-weapon States is liable to have considerable regional, or even global, security ramifications (see chaps. VII and VIII).

234. A decision to develop, build and test a nuclear weapon is complex. Following a political decision to acquire nuclear weapons, a non-nuclear-weapon State must develop the required technologies and ensure the supply of nuclear fissile material. Considerable research, development, engineering and industrial capacity are required to build facilities either to make enriched uranium or to extract plutonium from spent reactor fuel. To build such facilities is a complex and expensive task, which is beyond the domestic capabilities of many countries.

235. After the decision has been made as to how to acquire the fissile material, a State must decide whether to test its developed weapon. It is probable that a workable first-generation fission weapon could be developed without testing, although it is uncertain how reliable this device would be. The Hiroshima bomb was not tested, and design and construction may well be easier today with the use of supercomputers. To develop advanced nuclear weapons, such as fusion weapons, would, however, require testing.

B. Nuclear testing and its relationship to the continued development of warheads

236. The testing of nuclear warheads is a critical element in the production of nuclear weapons, because each new type of nuclear weapon typically requires the development of a new warhead. It is believed that most testing is done to develop specific new warheads, with half a dozen explosions required to develop a brand new design. Further tests are conducted to check weapons as they come off the production line, and also for their reliability when they reach the stockpile. 2/ Nuclear-test explosions are also used to research new kinds of nuclear weapons. "Weapons effects" tests are also carried out to measure the effect of radiation on military equipment. Most details of nuclear tests are kept secret.

/...

237. All five nuclear-weapon States conduct nuclear tests as part of their weapons programmes. Between 1945 and 1989 there were 1,819 internationally recorded tests (an average of one test every nine days) with a total yield of many hundred megatons (see table 1). Testing has been carried out on every continent except South America and Antarctica, as well as on a number of island territories in the Pacific Ocean. The United States, the Soviet Union and China test at isolated sites within their respective mainlands. The United Kingdom uses the American test site in Nevada. France has two test sites in French Polynesia.

Table 1. Recent nuclear testing data 3/

Country	First test	Current test site	Number of tests 1986	1987	1988	1989	All tests
United States	1945	Nevada	14	14	14	11	921
Union of Soviet Socialists Republics	1949	Semipalatinsk/ Novaya Zemlya	0 a/	23	17	7	642
United Kingdom	1952	Nevada	1	1	0	1	42
France	1960	Mururoa/ Fangataufa	8	8	8	8	180
China	1964	Lop Nor, Sinkiang	0	1	1	0	34

a/ The USSR held a moratorium on testing August 1985-February 1987.

238. Except for a few underwater tests, the early tests were carried out in the atmosphere, provoking widespread concern about the effects of radioactive fall-out. Since the 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (PTBT), the United States, the Soviet Union and the United Kingdom have conducted their testing at underground sites. France continued to carry out atmospheric tests on French territory in the South Pacific (see sect. F below) till 1974 when it changed to underground testing only. China ended atmospheric testing in Sinkiang in 1980. 4/

239. The nuclear-weapon States have based their decisions to develop new nuclear weapons, upgrade and test new nuclear-weapon systems on the following grounds: to ensure effectiveness of the nuclear deterrent by continued modernization of the nuclear stockpile; to maintain the reliability, survivability and safety of nuclear stockpiles; to allow the nuclear Powers to subject command and control equipment to nuclear effects; to permit development of smaller warheads with potentially limited collateral effects. 5/

/...

240. The nuclear-weapon States have used testing to amass a vast amount of weapons expertise and a wide range of nuclear weapons. They feel that nuclear weapons must be tested if they are to remain credible. While some nuclear explosions have been used to test trigger and safety mechanisms, many nuclear warhead components can be tested without an explosion.

C. Costs of acquiring and maintaining nuclear weapons

241. Both of the two previous United Nations studies on nuclear weapons (1968 and 1980) tried to estimate the costs associated with the acquisition of nuclear weapons by a State that decides on such an undertaking. The two studies agreed that a nuclear weapons programme would cost less in real terms to implement at their respective times of preparation than it did in 1945. This was attributed to technological progress in several fields, in conjunction with a wide dissemination of related knowledge within the framework of peaceful nuclear energy development. However, the two studies also agreed that any nuclear weapons programme would still be very expensive. The establishment and operation of a nuclear reactor or an enrichment plant or both would be very costly. The development of an advanced, dedicated delivery system might cost even more.

242. The costs of a nuclear reactor may be subdivided into three main categories: the cost of constructing the reactor, the fuel costs and the operational and maintenance costs. The cost of construction depends on the capacity, size, location, design and type of reactor to be built as well as on the availability of a skilled work force. Therefore, the investment cost for capital equipment is highly variable from reactor to reactor. The cost of fuel is more predictable, depending only upon price and quantity. Operational and maintenance costs also vary with the size and type of operation, although these costs are more stable from year to year.

243. The cost to a country of trying to develop and construct nuclear weapons and their delivery systems would be enormous and a call on the national budget that only a relatively small number of countries could sustain. Not only would a country have to divert a significant quantity of its human, technological and material resources to the project, but it would also have to devote its highest quality resources to this task. The infrastructure required to support a peaceful nuclear power programme is extensive; the demands of a nuclear weapons programme go well beyond that, particularly if the country has to develop an indigenous enrichment capacity to provide fissile materials for the weapons. Added to these already huge costs would be the expense of developing advanced dedicated delivery systems.

244. It is easier to construct and operate a dedicated plutonium production reactor than an electrical-power-producing reactor. Investment costs for the simplest type of graphite-moderated reactor giving enough plutonium-239 for two weapons annually (10 kg of plutonium) are estimated to be in the range of $25 to $50 million. The capital cost of a reprocessing plant to extract plutonium from irradiated fuel would amount to an additional $50 million. Personnel requirements for construction and operation are modest and plutonium could be produced four years after the start

of the construction. In order to obtain plutonium for 10 to 20 weapons per year with a safe and reliable reactor, investment costs would range up to perhaps $1,000 million and the project would require some 50 to 75 engineers and 150 to 200 skilled technicians. The time span until the first output of plutonium would be five to seven years. 6/

245. For an enrichment plant, costs may be categorized as for a reactor. The operational and maintenance costs are often proportional to the separation work actually done, which is indicative of the size and activity of the operation. This is often measured in mass separative work units (kg SWU) per time unit. The amount of separative work needed to produce a given quantity of enriched uranium depends on the type of plant, the quality of the "feed", i.e. the input, the level of enrichment of the final product and the residual U-235 content of the depleted "tails". For instance, to produce, in a certain plant, one kilogram of reactor fuel, enriched to 3 per cent from natural uranium with a 0.2 per cent uranium-235 content in the tails, 4.25 kg SWU is needed. To produce the same amount of weapon-grade material under the same conditions requires 226 kg SWU. 7/

246. Though costs can vary widely, all enrichment plants are expensive. In the United States, by the end of 1984, the total investment in plant and capital equipment for all three United States gaseous diffusion plants was $3.86 billion (an average of $1.28 billion each). According to unofficial sources, at the end of 1986, 2.59 million kg SWU went for United States defence activities, at the price of approximately $82-$100 per kg SWU. 8/

247. Some academic sources estimate that the total amount world wide of weapon-grade uranium produced since the Second World War ranges between 1,000 and 2,000 tons. Similarly, the total quantity of weapon-grade plutonium produced world wide amounts to 100-200 tons.

248. Currently, the United States is no longer producing enriched uranium for its nuclear weapons, since it has sufficient resources in its stockpile and in old weapons that it plans to scrap in the near future.

D. Peaceful uses of nuclear explosive devices

249. Since the advent of the nuclear age in 1945, the international community has sought both to use nuclear energy for peaceful purposes and at the same time to prevent the spread of nuclear weapons. The issue of peaceful nuclear explosions (PNEs) is closely connected with the pursuit of these two goals. While nuclear explosions have a potential of being carried out for civil purposes, the practical technical and economic benefits of such use of a nuclear device remain in doubt. Moreover, the prevalent view is that the technology for developing any explosive nuclear device is not distinguishable from that involved in the development of a nuclear weapon and that the explosion of such a device for peaceful purposes is indistinguishable from a nuclear-weapon test. A non-nuclear-weapon State capable of exploding a nuclear device could therefore emerge as a nuclear-weapon State in a significantly shorter time. 9/

/...

250. Two broad categories of potential peaceful use of nuclear explosive devices have been identified: (a) excavation and landscaping (e.g. canal and dam construction) and (b) contained application (e.g. curbing runaway gas well fires, stimulating oil and gas production, creating storage cavities and conducting deep seismic soundings). Soviet peaceful nuclear explosions have encompassed all of the uses described above. 10/

251. The United States and the Soviet Union, hopeful of achieving technical success and economic advantages from peaceful nuclear explosions, each began conducting PNE-related test explosions in the 1960s. France carried out research or peaceful nuclear explosions but did not conduct any tests. China and the United Kingdom have never expressed any interest in peaceful nuclear explosions, and there are no indications that they have ever had such programmes. In 1974 India announced that it had carried out a peaceful nuclear explosion; it is the only non-nuclear-weapon State to have done so. This event aroused concern among other countries. 11/

252. The United States peaceful nuclear explosions programme, established in 1957, consisted of an active research and development effort and 12 actual nuclear field tests to investigate possible uses for gas stimulation and large-scale excavation. The advantages of using nuclear explosions for these purposes were not demonstrated by the programme. Because of this and the increasing public concern for the environment and possible increases in radioactivity, the United States terminated its programme in 1977. 12/

253. The first explosives used in the United States peaceful nuclear explosions programme were existing nuclear weapons modified to meet underground emplacement conditions. As experimental data became available, however, it became clear that the United States peaceful nuclear explosion devices would require special characteristics to minimize health and safety effects; these characteristics would include low-fission explosives for excavation and all-fission devices to minimize residual tritium for use in oil and gas stimulation. All testing of the devices was done at national test sites, while the analysis of each event focused on whether the device performed as expected and what radioactive elements were present. 13/

254. The Soviet Union also had an active peaceful nuclear explosions programme, conducting over 100 detonations since 1965. However, the programme has been seriously scaled back. Excavation applications apparently were abandoned a decade ago, owing to discouraging experimental results and strong public objections on environmental grounds. The main Soviet efforts now seem to focus on creating underground facilities for storage of gas condensate and conducting deep seismic soundings. 14/

255. Five major treaties on arms limitation and disarmament deal in whole or in part with the issue of peaceful nuclear explosions, all attesting to the similarity of nuclear explosive devices for military and for peaceful purposes (see chap. VIII).

256. The original optimism on the possible benefits of the PNE technology has now been reversed. The combination of environmental problems, delicate arms control issues, cost and security and safety problems have all contributed to a common understanding that the PNE technology is generally impractical.

E. Physical, medical and environmental effects of nuclear weapons production

257. The complete nuclear-weapons production cycle comprises many operations, i.e. mining and milling of uranium, uranium enrichment, reactor fuel fabrication, operation of reactors for plutonium production, spent fuel reprocessing, weapons manufacture, handling of weapons, dismantling of weapons and final disposal of waste. Many of these operations are also common to civilian use of nuclear energy. Most, if not all of them, are associated with possible risks to the personnel involved and to the environment. Accidental releases of radioactive substances and chemicals during ongoing processes or by effluents, transports and so on resulting from mismanagement of wastes may cause environmental damage.

258. The United States nuclear warhead production industry currently consists of 17 major facilities in 13 states. 15/

259. There has been increased scrutiny by the United States of its nuclear reactors used to produce materials for nuclear weapons, revealing safety concerns at a number of the United States nuclear-material-production facilities. Therefore, all of the United States Department of Energy's nuclear-weapons-material-producing reactors have been shut down as at early 1990. As a result, the United States has not produced any new tritium since at least June 1988, as the Department's three operational tritium production reactors at the Savannah River facility, in the state of South Carolina, have all been shut down.

260. The United States is estimated to have about 500 metric tons of weapon-grade uranium, enough to support all existing United States nuclear weapons. 16/ In 1964, President Lyndon Johnson decided that the United States stockpile of highly enriched uranium was sufficient to support American nuclear weapons requirements. Since then the United States has not produced any additional highly enriched uranium for weapons. 17/

261. The United States currently has about 100 metric tons of plutonium, enough to support its current stockpile of nuclear weapons. 18/ In addition to the plutonium in existing nuclear warheads, the United States has reserve and scrap plutonium that could, depending on modernization requirements and retirements, continue to support a nuclear arsenal for some time. 19/ United States legislation prohibits diversion of plutonium from civilian power plants to weapons use.

262. The Soviet Union is thought to have built a total of 14 military nuclear reactors, the same number that the United States originally built. Four of them have been closed down. The 10 Soviet reactors that are still in service will soon have been operating for about the same length of time as United States military reactors, before the United States reactors were shut down. 20/

263. The Soviet Union has announced that in 1989 it stopped production of enriched uranium, that it closed in 1987 one reactor that was producing weapon-grade plutonium and that it plans to close down in 1989-1990 a few more such reactors. In 1989, the Soviet Union announced that it planned to decommission by the year 2000 all plutonium-producing reactors. Four reactors producing weapon-grade plutonium in the vicinity of Kyshtym will be shut down by the end of 1990. Out of six plutonium-producing reactors that will still be operating, three reactors will be closed by 1996 and the last three before the year 2000. 21/

264. The Soviet Union has also been experiencing difficulties with its nuclear-weapons production facilities. It has been reported that the Kyshtym Industrial Complex, established in 1946 and therefore the oldest nuclear-weapons production facility in the Soviet Union, was experiencing difficulties similar to those of its American counterparts. The plant has experienced severe radioactive and toxic pollution, critical mechanical lapses and public fears about health threats. This is not a new problem for the Soviet Union. Mismanagement of nuclear waste caused a huge explosion there in 1957 that showered hundreds of square miles with dangerous radioactive particles. It forced the evacuation of more than 10,000 people and created a radioactive zone 65 miles long and almost 6 miles wide. In addition, the Soviet Union poured caesium, strontium and other nuclear wastes directly into a lake within the complex, making it unfit for human use. More than 30 years later water reserves in the surrounding area are still undrinkable. 22/

265. The 1957 accident at Kyshtym, which was described in detail by the Soviet press 32 years later, coupled with the accident at Chernobyl in April 1986, has also caused popular anxiety in the Soviet Union about nuclear technology. As a result of various incidents, both in the Soviet Union and in the United States, domestic concerns about the dangers people face from the weapons industry have begun to enter the debate about the safety of nuclear facilities. 23/

266. These concerns have prompted the United States Department of Energy to propose spending $28.6 billion over the next five years to correct the conditions at civil and military nuclear sites around the United States. The money would be used to clean up pollution, to repair equipment and for research to develop new methods to dispose of radioactive and chemical waste. The plan is intended to correct nuclear and chemical contamination and repair damage at 94 nuclear sites in 19 states in the United States, of which 72 are no longer active. 24/

267. Under the plan, at least $13 billion is to be spent on the disposal of low- and high-level radioactive wastes. The low-level waste includes cardboard boxes, gloves and other material contaminated with radioactive substances, which are not acutely harmful but can be dangerous with long-term exposure. The high-level waste consists of radioactive elements like caesium and strontium. Most of these wastes are stored as liquids. They emit penetrating radiation that can be lethal near the storage vessels even after very short exposure. 25/

268. Among the problems identified at United States nuclear-weapons production plants were: (a) releases of radio-nuclides and other harmful substances into the air, water and soil; (b) plants run without adequate worker protection or safety precautions; (c) toxic and radioactive waste accumulating in thousands of dump

sites; and (d) hazardous materials being unsafely transported through heavily populated sections of major American cities. 26/

269. There is little information as to whether the other three nuclear-weapon States are having any problems with their military reactors on a scale similar to those being experienced by the United States and the Soviet Union. However, the United Kingdom has experienced some contamination, on at least one occasion, from a reactor used for production of weapon-grade fissile material. France has not met with any similar difficulties, according to French officials.

F. Physical, medical and environmental effects of testing

270. Radioactive materials from atmospheric testing occasionally caused strong local contamination and were also distributed globally. However, since the signing of the PTBT, the United Kingdom, the Soviet Union and the United States have not conducted atmospheric tests.

271. Continued testing throughout the 1950s spread radioactive substances over Utah and Nevada and over ships and islands in the Pacific near the Bikini Atoll tests. Army troops were also placed near the atomic test sites in 1952 and 1953 as part of an exercise to test the effects of the use of nuclear weapons on combat readiness. 27/ A higher incidence of cancer has been reported in these troops, although an explicit link to the tests has not been established. The concern about this global contamination led the United Nations to establish in 1955 the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). This Committee has reported to the General Assembly on a regular basis on the levels of contamination and the associated health effects.

272. Fall-out has affected test areas, some of which have not yet been restored to safe, habitable conditions. Different components in the fall-out from a nuclear test remain radioactive for periods varying from a few days to many millennia. Despite precautions being taken, weather conditions occasionally led to significant amounts of radioactive material being carried to nearby inhabited regions. Some biological effects of the testing have been clearly demonstrated, such as the thyroid tumours following exposure after atmospheric tests of children on the Marshall Islands. Other alleged effects of exposure on, for example, troops from the United States and the United Kingdom, and of the population in the contaminated areas in the vicinity of the test sites are still being studied.

273. The effects of underground testing depend on the yield and depth of the blast as well as the geological character of the test site. The bulk of the radioactive debris is trapped within vitrified rock, which is formed in the explosion chamber during the test. Immediate releases of radioactive substances can occur by the venting of gas to the surface through the shattered rock above the chamber. While it is normal for rigorous safety precautions to be in force at underground test sites, instances of venting, of varying seriousness, have occurred. The health of test site workers, who work in close proximity to a range of radiation hazards, is closely monitored. 28/

274. For testing to be safe in the longer term, rock formations at test sites must be sound enough to prevent the leakage of high-grade radioactive material into the ground water over several thousand years. Critical factors include the leachability of the radioactive waste, the flow rate of the ground water, the absorption character of surrounding rock and the isolation of the site itself. 29/ Scientific studies have reached various conclusions on the likelihood and severity of future leakages. However, there is a natural and widespread concern that test sites may not prove able to contain radioactive waste and that serious leaks could have environmental and medical consequences.

275. Underground nuclear tests also produce geological disturbances. The underground cavity formed by the explosion soon collapses, causing some surface disturbance. Seismic waves from the blast may affect the whole test site, adding to concerns about its long-term integrity and causing other damage in some cases, such as marine landslides. Small seismic waves can be detected from great distances. However, underground nuclear tests are not thought to trigger larger earthquakes.

276. There are two test sites in the Soviet Union for the conduct of nuclear tests - one near the town of Semipalatinsk (Kazakhstan) and one on the island of Novaya Zemlya, between the Barents Sea and the Kara Sea in the Arctic Ocean. The first Soviet atomic bomb was exploded at the Semipalatinsk site in 1949 and in 1953 a hydrogen bomb was exploded there. Prior to 1963, atmospheric nuclear tests were carried out at that site.

277. In 1989, two commissions of experts were established at the request of public organizations in Kazakhstan, and they have brought to light a number of factors reflecting the adverse effect of tests on the population and on plant and animal life in areas of Kazakhstan adjacent to the test site. In particular, it has been determined that during the 14-year period when atmospheric tests were conducted, approximately 10,000 people were exposed to radiation in areas immediately adjacent to the test site. Among these 10,000, the average equivalent dose varied from 0.02 to 1.6 sievert (Sv). The remaining population received less than 0.02 Sv. 30/ (As a comparison, for a professional who has to deal with ionizing radiation, an equivalent dose of up to 0.05 Sv over a year is not considered to be a health hazard, according to current international standards.)

278. Between 1959 and 1987 the mortality rate from leukaemia tripled in the Semipalatinsk region. Birth defects resulted in a significant increase in infant mortality. The incidence of births of children with subsequent mental retardation was three to five times higher in the areas adjacent to the test site than in the country as a whole. In a sample survey of the population conducted in 1989, almost half those examined showed decreased immunological resistance. As early as 1962, a medical commission of the Academy of Sciences of the Kazakh SSR established that the incidence of malignant tumours in the Semipalatinsk region was 35 per cent higher than average for the Republic. 31/

279. Following the conversion of the Semipalatinsk test site to use solely for underground tests, the radiation situation improved significantly. The level of background radiation is now almost the same as natural background radiation.

Nevertheless, after each underground nuclear explosion, water is lost from the wells and water supply and sewage pipes burst. Cracks appear in the walls of buildings. Even today, unusually large numbers of people are treated in polyclinics and both children and teachers show a sharply reduced ability to work.

280. The United States test area is situated in Nevada. Early United States nuclear tests had been carried out in New Mexico, Mississippi, Colorado, in the central Pacific on atolls in the Marshall Islands, the Northern Line Islands and in the Aleutian Islands. The Nevada test site was chosen as a continental proving ground in December 1950 to reduce the expense and logistic problems of testing in the Pacific.

281. The Nevada test site has been used for both atmospheric and underground testing. It has been reported that in the 1950s and 1960s employees at the site had been exposed to dangerous levels of radiation during post-explosion work. The Office of Technological Assessment has also disclosed that 126 underground tests since 1970 have released roughly 54,000 curies of radiation, which is only a very small release compared with that emanating from an atmospheric explosion. The Office has concluded that these releases from underground tests have not jeopardized the health of nearby residents.

282. The United Kingdom uses the Nevada test site for its underground tests. Early United Kingdom tests had been carried out in the central Pacific and in Australia.

283. There is little information available about the conditions at the Chinese test site at Lop Nor in Singkiang. The testing base covers an area of more than 100,000 km^2 in the Gobi desert. Both atmospheric and underground tests have been conducted there.

284. Nuclear testing in the South Pacific has become an area of contention between some of the nuclear-weapon States and a number of South Pacific States.

285. French nuclear testing takes place on the atolls of Mururoa and Fangataufa in the territory of French Polynesia. France began atmospheric testing there in 1966, switching to underground testing alone in 1974. Recently, France announced that its test programme would be reduced from eight to six tests annually and the level of secrecy surrounding the programme would be reduced.

286. There has been a long international debate about the safety and desirability of French tests. France says that testing is necessary to ensure the effectiveness of its nuclear forces. It is satisfied that the testing programme is safe. The test sites are isolated (1,500 people live in a 500 km radius) and a variety of safety precautions have been taken.

287. French nuclear testing is a matter of concern to most South Pacific countries. They strongly object to manifestations of nuclear weaponry in the South Pacific, a sentiment reflected in the Treaty of Rarotonga (see chap. VII), and have made many calls for France to stop testing in the region. In 1973, upon the request of Australia and New Zealand, the International Court of Justice indicated that the Government of France should avoid nuclear tests causing the deposit of

/...

radioactive fall-out on the territory of Australia, New Zealand, the Cook Islands, Niue or the Tokelau Islands. However, in 1974 the Court found that France had entered into a commitment not to carry out atmospheric tests in the South Pacific and that, accordingly, the Australian and New Zealand claims no longer had any object. 32/ Concerns continue to be expressed about the environmental and health effects of French underground testing. In particular, some scientists feel there is a significant risk of radioactivity leaking into the surrounding ocean over time. 33/ However, France has allowed several independent studies which have shown no significant radioactive pollution of the areas investigated. 34/

Notes

1/ NPT/CONF.III/64/I.

2/ Effects of a Comprehensive Test Ban Treaty on United States National Security Interests, hearings before the Panel on the Strategic Arms Limitation Talks and the Comprehensive Test Ban Treaty of the Intelligence and Military Application of Nuclear Energy Subcommittee of the Committee on Armed Services, House of Representatives, 95th Congress, second session, August 1978. See also Announced United States Nuclear Tests, July 1945-December 1984, Department of Energy, 1985; Thomas B. Cochran et al., eds. Nuclear Weapons Databook, Vol. II: United States Nuclear Warhead Production, Cambridge, Ballinger, 1987, pp. 44-47 and pp. 151-178; Test Ban Issues: Hearing of the Committee on Foreign Relations, United States Senate, 100th Congress (second session, 6 October 1988, Washington, US Government Printing Office, 1989; and Nuclear Weapons and Security: The Effects of Alternative Test Ban Treaties: Report, United States House of Representatives, Committee on Foreign Affairs, 101st Congress, first session, June 1989, Washington, US Government Printing Office, 1989.

3/ "Nuclear Notebook", Bulletin of the Atomic Scientists, vol. 46, No. 3 (April 1990), p. 57; see also Ragnhild Ferm, "Nuclear Explosions", in SIPRI Yearbook 1990, New York, Oxford University Press, 1990, pp. 56 and 57 (table 2.A.4).

4/ In the course of undergound nuclear testing, a shaft is drilled in suitable rock formations to a depth of 200-1,500 metres. A canister containing the nuclear device and equipment to monitor the blast is placed in it, and cables are run down the shaft to transmit data to the surface. The shaft is then plugged with debris and sealing agents to prevent the release of radioactive gases. Data is received as the charge is detonated and small samples may be taken from the rock structure after the blast. In "weapon effects" tests the procedure is rather different, involving the construction of large, accessible underground caverns to hold equipment, with barriers to shield the equipment from the blast. Ibid. See also Ragnhild Ferm, "Nuclear Explosions", in SIPRI Yearbook 1987, p. 46. On the mechanics of underground testing, see Cochran, et al., op. cit., pp. 44-47.

5/ See Steven Fetter, Toward A Comprehensive Test Ban, Cambridge, Ballinger, 1988, chap. 2, pp. 33-68.

/...

Notes (continued)

6/ Cost estimates in this paragraph are those given in the 1980 United Nations nuclear-weapons study, adjusted to current United States dollar value. The estimates do not reflect the fact that inflation has been more rapid in many other States, nor the existence of other factors that may influence costs.

7/ Allan S. Krass, Peter Boskma, Boelie Elzen and Wim A. Smit, Uranium Enrichment and Nuclear Weapon Proliferation, London, Taylor and Francis Ltd., 1983, chap. 5, pp. 93-119; Cochran et al., op. cit., pp. 125-135.

8/ Thomas B. Cochran, et al., vol. III, pp. 130 and 131.

9/ See Effects of a Comprehensive Test Ban Treaty on United States National Security Interests Hearings, op. cit., p. 57.

10/ For a detailed discussion of PNEs, see Iris Y. P. Borg, "Nuclear Explosions for Peaceful Purposes", in Jozef Goldblat and David Cox, eds., Nuclear Weapons Tests: Prohibition or Limitation?, New York, Oxford University Press, 1988, pp. 59-74; see also Ragnhild Ferm, "Nuclear Explosions", SIPRI Yearbook 1988, p. 66.

11/ See Bhupendra Jasani, "Introduction to Part IV", in SIPRI, eds., Nuclear Energy and Nuclear Weapon Proliferation, London, Taylor and Francis, Ltd., 1979, pp. 288 and 289; and D. Davies, "Peaceful Applications of Nuclear Explosions", in the same volume, pp. 300 and 301.

12/ Borg, op. cit., pp. 59-67.

13/ Ibid., pp. 60 and 61.

14/ Ibid., pp. 67-69.

15/ Cochran, et al., op. cit., p. 26.

16/ Cochran, et al., op. cit., pp. 5, 75, 83 and 191.

17/ Ibid., pp. 5, 82 and 85.

18/ Ibid., p. 75, as at end of fiscal year 1984.

19/ Ibid., pp. 74-78. With the completion of the INF Treaty and the likelihood of a START Treaty in the future, sufficient plutonium will be available from the warheads on missiles earmarked for dismantling for future modernization.

20/ Center for Defense Information, The Defense Monitor, vol. 18, No. 4, 1989.

21/ Official Records of the General Assembly, Forty-fourth Session, Plenary Meetings, 6th meeting.

/...

Notes (continued)

22/ See James E. Oberg, Uncovering Soviet Disasters: Exploring the Limits of Glasnost, New York, Random House, 1988, chap. 13, "The Urals Disaster", pp. 211-228. See also John May, The Greenpeace Book of the Nuclear Age, New York, Pantheon, 1989, pp. 119-123 and 348.

23/ Sources, Effects and Risks of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, 1988 report (United Nations publication, Sales No. E.88.IX.7).

24/ See Philip Shenon, "Atomic Cleanup is Seen Costing $92 Billion", in The New York Times, 5 January 1989, p. A16; Keith Schneider, "US Plans Study of Weapons Plants' Effects on Public", in The New York Times, 13 January 1990, p. A6; and Keith Schneider, "Cost of Cleanup at Nuclear Sites is Raised by 50%", in The New York Times, 4 July 1990, p. A1. A detailed Department of Energy five-year plan for site clean-up and waste management was prepared in November 1989.

25/ Ibid.

26/ Todd Perry, David Lewis and Janna Rolland, "The US Nuclear Weapons Production Complex: A Public Health and Safety Emergency", in PSR Monitor, vol. 5, No. 1, January 1989, p. 2.

27/ Robert C. Williams and Philip L. Cantelon, eds., The American Atom, Philadelphia, University of Pennsylvania, 1984, pp. 177 and 178.

28/ See A. C. McEwan, "Environmental Effects of Underground Nuclear Explosions", chap. 4 in Goldblat and Cox, op. cit., pp. 75-91.

29/ Ibid.

30/ Pravda, 12 February 1990. On the Kazakhstan public organizations that have requested inquiries into testing dangers, see Michael R. Gordon, "Soviets Cut Back Nuclear Testing as Hazards Become a Local Issue", in The New York Times, 8 July 1989, p. A3; and Paul Quinn-Judge, "Activists Mute Soviet Nuclear Tests", in The Christian Science Monitor, 12 April 1989, pp. 1 and 2.

31/ Pravda, 6 April 1990.

32/ Nuclear Tests (Australia v. France), Interim Protection, Order of 22 June 1973, I.C.J. Reports 1973, p. 99; Nuclear Tests (New Zealand v. France) Interim Protection, Order of 22 June 1973, I.C.J. Reports 1973, p. 135; Nuclear Tests (Australia v. France), Judgment of 20 December 1974, I.C.J. Reports 1974, p. 253, Nuclear Tests (New Zealand v. France) Judgment of 20 December 1974, I.C.J. Reports 1974, p. 457.

33/ Manfred P. Hochstein and Michael J. O'Sullivan, "The underground hydrology of Mururoa Atoll", in New Zealand Engineering, Wellington, 1 October 1986, pp. 47-49.

/...

Notes (continued)

34/ H. R. Atkinson, P. J. Davies, D. R. Davy, L. Hill and A. C. McEwan, Report of a New Zealand, Australian and Papua New Guinea Scientific Mission to Mururoa Atoll, Wellington, New Zealand Ministry of Foreign Affairs, 1984, pp. 10-12; Fondation Cousteau, Mission scientifique de la Calypso sur le site d'expérimentations nucléaires de Mururoa, Paris, Fondation Cousteau, 1988, pp. 49-52.

CHAPTER VI

EFFECTS OF USE OF NUCLEAR WEAPONS AND CONSEQUENCES OF NUCLEAR WAR

A. General

288. The existing knowledge of the effects of the use of nuclear weapons is far from complete. In only two instances were nuclear weapons used in actual war conditions, against the Japanese cities of Hiroshima and Nagasaki in 1945. The outcome of these explosions has been painstakingly investigated, yet considerably different data are given by different sources, in particular with regard to the number of casualties. Even in recent years, new findings have been brought to light about the detailed effects of the bombings of Japan.

289. The studies on the effects of a nuclear war are generally based on data from Hiroshima and Nagasaki, nuclear-weapon testing and extrapolations or scientific hypotheses that by definition cannot be verified. Irrespective of the sophistication of the various models applied in the different studies, it should be borne in mind that no desk calculations could give a true picture of the consequences of nuclear warfare. The accounts given below should therefore be considered only as indications of the magnitude of the effects of nuclear war as described in these studies.

290. Studies carried out to determine the effects of the use of nuclear weapons have all used different war scenarios and applied various other assumptions. The scenarios ranged from the explosion of one nuclear weapon to an all-out nuclear exchange. Apart from the number of weapons used, other scenario parameters are, for instance, the explosive yield and height of burst of the individual weapons, the character of their targets, especially the population density in the target area, and climate and weather conditions. The results have usually been presented as estimates of the number of people killed and injured, as well as of material damage to built-up areas, loss of industrial capacity, and so forth.

291. Should large numbers of nuclear weapons ever be used, the total effect would be much larger and more complex than the sum of individual cases. Immediate damage may be enhanced by interactions of a direct and physical nature. Important additional uncertainties pertain to the overall social, economic and political aftermath of the sudden and widespread devastation that a nuclear war would entail. There are also long-term, large-scale physical consequences, including climatic effects, of a war involving many nuclear explosions. All of these large-scale consequences will affect non-combatant nations, partially on a global scale, for a long time after the war.

B. Effects of one nuclear explosion

292. The explosion of a nuclear weapon causes damage in several ways: intense thermal radiation, a powerful blast wave and nuclear radiation from the fireball and from radioactive fall-out. There is also a pulse of electromagnetic radiation

harmful to electrical systems. Of these, the fall-out has a delayed effect, while all the others are immediate. 1/

293. When a nuclear weapon is exploded above ground, the first noticeable effect is a blinding flash of intense white light. The light is emitted from the surface of the "fireball", a roughly spherical mass of very hot air (the temperature is of the order of 10 million°C) and weapon residues, which develops quickly around the exploding weapon and continues to grow until it reaches a maximum radius, which depends on the yield. 2/ During this time, and for some time after, the fireball emits thermal radiation both as light and - mainly - heat. When the fireball rises, it cools off and is gradually transformed into a huge mushroom-shaped cloud. A column of dust and smoke sucked up from the ground forms the stem of the mushroom. After some 10 minutes, when the cloud is fully developed, it will have a height and a diameter of several kilometres, dependent on the yield. By then, about one third of the explosive energy has been released as heat. 3/

Thermal radiation

294. The effects of thermal radiation would be manifold. Within and close to the fireball, everything would be vaporized or melt. The thermal radiation could be expected to kill or severely injure people directly exposed to it at relatively large distances. Materials that are easily ignited, such as thin fabrics, paper or dry leaves, may catch fire at even longer distances. This may cause numerous additional fires, which under some conditions may form a huge fire storm enveloping much of the target area and adding numerous further casualties. That was the case in Hiroshima, although it is considered less likely in modern cities. 4/

Air blast

295. The blast wave carries about half the explosive energy and travels much slower than the various forms of radiation, but always at supersonic speed. The arrival of the blast wave is experienced as a sudden and shattering blow, immediately followed by a hurricane-force wind directed outwards from the explosion. Near the explosion, virtually all buildings would be utterly demolished and people inside them killed. At somewhat larger distances, ordinary buildings would be crushed or heavily damaged by the compressional load as they would be engulfed by the blast overpressure and the wind drag. People inside could be crushed under the weight of the falling buildings, hurt by the flying debris of broken windows, furniture, etc., or even suffocated by the dense dust of crushed brick and mortar. All the primary blast destruction would take place during a few seconds. 5/

296. Some of the energy in the blast is transferred to the ground, creating a shock wave in the underlying soil or rock strong enough to damage even fortified underground structures. The transfer of energy would become more efficient the closer to ground level the explosion occurs.

Nuclear radiation

297. Before any visible phenomena occur, the exploding device starts to emit an intense burst of neutrons and gamma rays. Virtually all of this radiation is

/...

released during the first one or two seconds. It is rapidly attenuated with distance as it travels through the air. For an explosion similar to those over Hiroshima or Nagasaki, this radiation is strong enough to render human beings in the open unconscious within minutes at distances up to 700 or 800 m from ground-zero. 6/ The exposed persons, if they survive the blast and heat, would die in less than one or two days from the radiation injury. The radiation received at a distance of 1,300-1,400 m from such an explosion would also be fatal but death may be delayed up to about a month. At 1,800 m or more from ground-zero few if any acute radiation injuries would be expected to occur. However, late radiation injuries may be induced by lower radiation levels. In addition, acute radiation sickness caused by non-lethal doses could trail off with a state of general weakness protracted over months and years. 7/

Electromagnetic pulse

298. Simultaneously, a small part of the gamma ray energy is converted to electromagnetic energy through interaction with the surrounding air and develops a strong electromagnetic field, which is also propagated outwards (see figure 1). This phenomenon, known as electromagnetic pulse (EMP), takes the form of a very short burst of electromagnetic waves in the radio frequency spectrum, up to at least 1 MHz, which trails off within about one thousandth of a second. Electronic equipment might suffer EMP damage even if it were not connected to any antennae. 8/

Nuclear fall-out

299. The fireball, and later the cloud, contains most of the radioactive atoms, mostly fission products, that were formed in the explosion. While the total weight of these fragments is small, about 1 kg, their combined activity one hour after the explosion equals that of several thousand tons of radium (although the emitted radiation is somewhat different). This activity decays rapidly, however; during the first two weeks it decreases to one thousandth of what it was one hour after the explosion. As the cloud develops, the radioactive atoms are incorporated in larger particles formed by condensing vapours and mixed-in dust and dirt. The range of the radiation is relatively short compared to either the height of the cloud base or the size of the devastated area. For this reason, the radioactive particles in the cloud do not constitute a health hazard until they are deposited on the ground as radioactive fall-out. 9/

/...

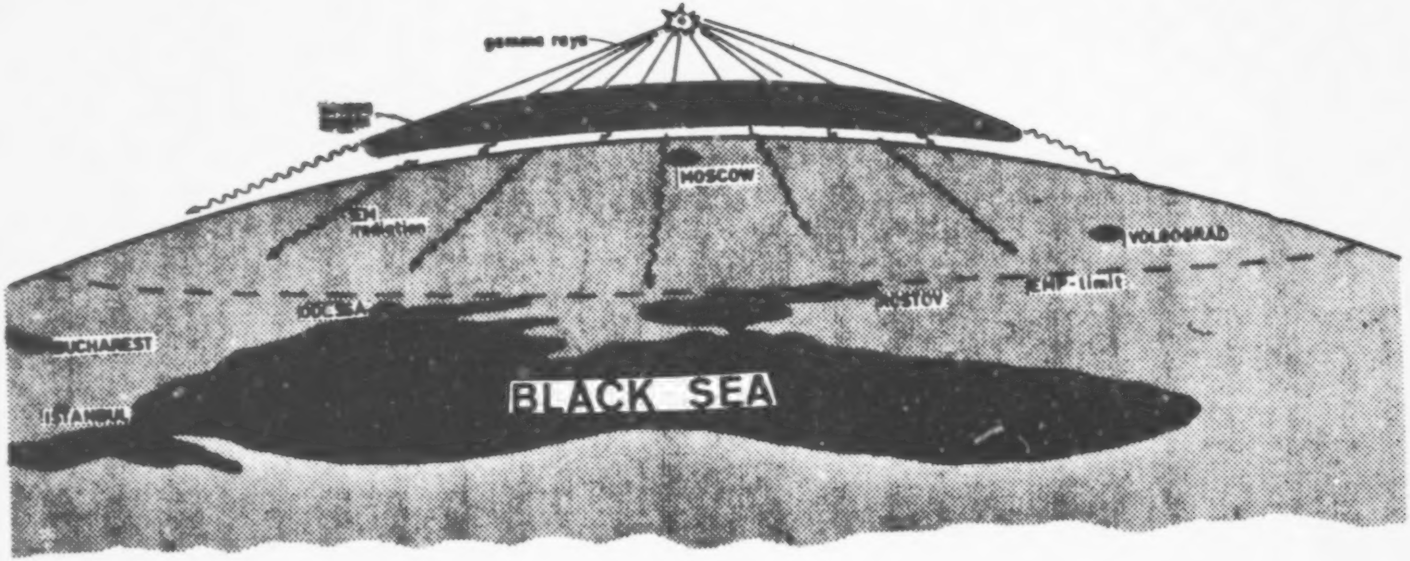

gamma rays
EM radiation
MOSCOW
VOLGOGRAD
EMP-limit
ODESSA
ROSTOV
BUCHAREST
ISTANBUL
BLACK SEA

Figure 1. High-altitude electromagnetic pulse

A nuclear explosion at, say, 100 km above the Earth will create EMP phenomena within a 1,200 km circle. If, for instance, Moscow were chosen as ground-zero, the EMP disturbance would reach from the Kola Peninsula to the Black Sea. It would also cover parts of Finland, Poland and Romania. (The heights of the burst and the source region are greatly exaggerated in comparison to the curvature of the Earth.)

/...

300. The radioactive cloud drifts, changes shape and eventually disintegrates under the action of the winds at those altitudes where it is stabilized. At the same time, the particles carrying the activity subside with speeds that depend strongly on their size. In the case of an air burst, most particles will be very small and it may take from days to years for them to reach the ground. By that time they have lost most of their activity and have been scattered over a wide area. Fall-out over intermediate times may be denoted tropospheric, while the very slow deposition of particles injected into the stratosphere is usually referred to as global fall-out. This fall-out radiation does not cause any acute ill effects, but over the decades to follow it will contribute to the occurrence of "late effects" (additional cancers and genetic injuries). 10/

301. When the nuclear weapon explodes at or close to the ground, with the fireball in direct contact with the surface, thousands of tons of soil are injected into the hot vapours. Large (diameters up to one millimetre or more) particles then carry a significant part of the residual activity. These particles come down to earth in a matter of hours or even minutes and create an intensely radioactive contamination field in the downwind vicinity of ground-zero. This so-called immediate fall-out gives rise to acutely lethal radiation doses for unprotected people over large areas. The possibility of late radiation injuries in this area is also much larger than in the case of an air burst. 11/

302. The size of the areas affected by the various effects described above will depend primarily on the explosive yield and the height above the ground of the explosion. It is also influenced by other factors specific to each situation such as weather conditions. Some of these factors are not yet fully understood. 12/ Wind velocity is particularly important for fall-out.

303. It is generally considered that the area on the ground affected immediately would be circular. Its size increases with increasing yield but in less than direct proportion to it. Roughly, ten-fold or hundred-fold increases in the yield produce five-fold and twenty-fold increases respectively in the area devastated by air blast. 13/ The area exposed to a certain level of thermal radiation increases more rapidly with yield than does that affected by air blast. This implies that thermal effects - fires and burns - will become progressively more dominant with increasing weapon yields. Conversely, the initial nuclear radiation loses most of its importance when the yield increases.

304. Areas of damage caused by different effects will vary with the height of burst, generally decreasing somewhat with decreasing height. These variations are relatively unimportant in comparison to the most dramatic additional effect of explosions close to the ground surface, i.e. the generation of local radioactive fall-out, as described above. In a matter of hours, the fall-out will contaminate an area downwind of the explosion that is very large compared to that affected by blast and heat. The size of the contaminated area is expected to be roughly proportional to the fraction of the explosive yield due to fission, although the actual distribution of fall-out is determined by winds and precipitation. 14/

305. Another influence of variations in the height of burst relates to EMP. Surface or low air bursts will generate EMP that may have harmful effects on electrical and electronic equipment out to a distance of about 3-10 km from ground-zero, depending on the explosion yield and the equipment sensitivity. The strength of the EMP at the ground will then decrease with increasing height of burst up to an altitude of 10 to 15 km. When bursts occur at still higher altitudes, a strong EMP will again be experienced on the ground. This is due to the combined effects of atmospheric density variation in the altitude and the geomagnetic field. This EMP covers a wide area, since it extends outwards in all directions as far as the line of sight from the burst point. A nuclear explosion at an altitude of 80 km would affect a circular area with a radius of about 1,000 km. Thus a high altitude burst might cause EMP damage over entire countries while all other effects (except possibly flash blindness at night) would be negligible. 15/

C. Levels of immediate destruction in various scenarios

1. Effects of a nuclear explosion over cities

306. Many of the studies referred to above have described the immediate consequences of nuclear air bursts - often with high explosive yields - over large cities. The number of fatalities and level of destruction in such a scenario depend on many factors, including the size of the city and the distribution of its population in relation to weapon yield, the height of burst and ground-zero location.

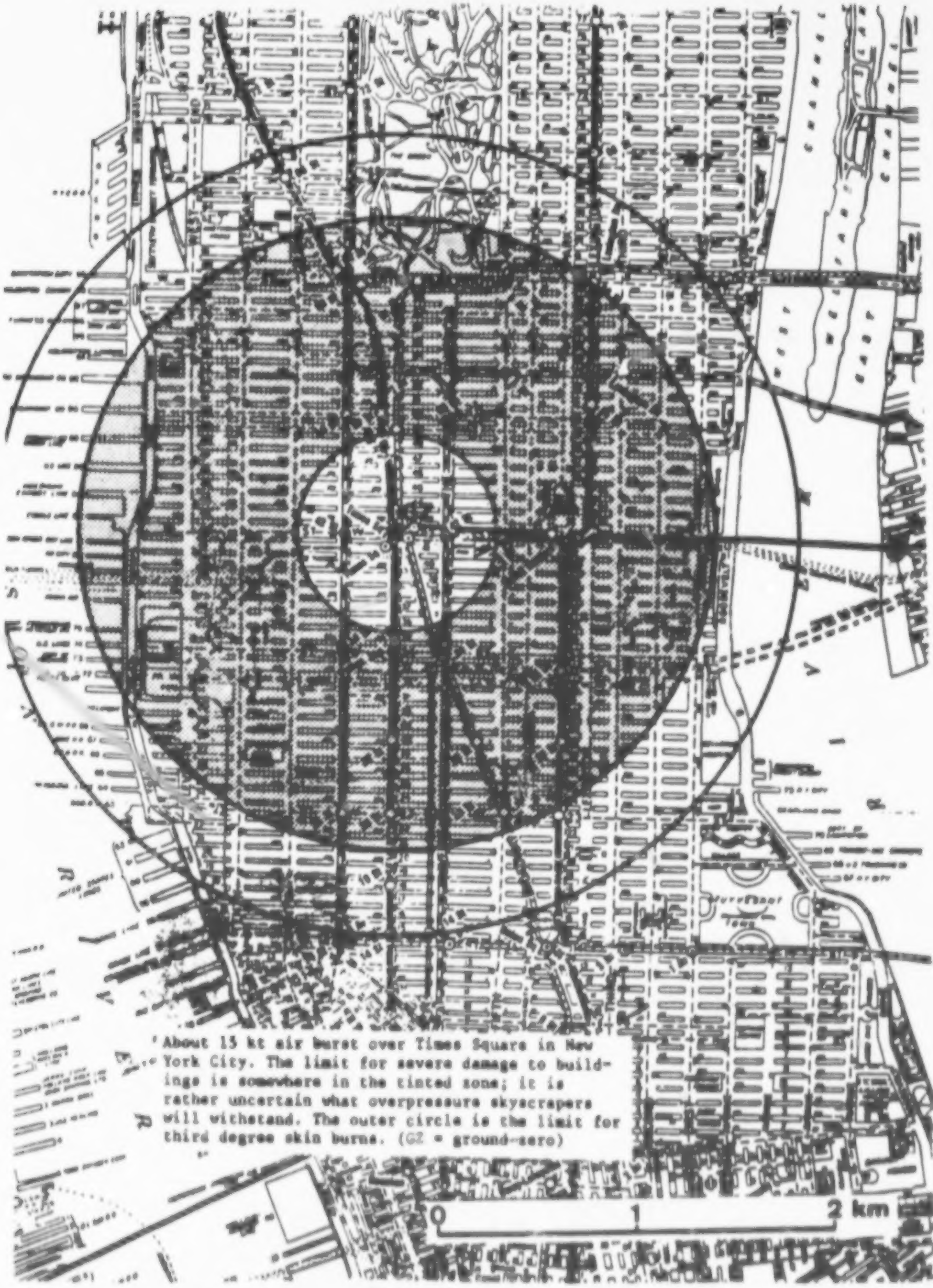
307. That one nuclear weapon of relatively low yield can destroy a city of intermediate size and kill a large portion of its population was convincingly demonstrated in August 1945. The actual numbers of people killed or injured in Hiroshima and Nagasaki are still under debate. In the case of Hiroshima, between 310,000 and 320,000 people were exposed to the various effects of the atomic explosion. Of these, between 130,000 and 150,000 had died by December 1945 and an estimated 200,000 by 1950, if latent effects are included. In Nagasaki, the corresponding numbers are 270,000-280,000, 60,000-80,000 and 100,000. 16/

308. The 1980 United Nations study reported the consequences of a 100 kt low airburst over the centre of a European city with 0.5-1 million inhabitants. Scientists had estimated that such an explosion could kill up to half the population, that at least half of all buildings within a radius of 5-6 km would be destroyed by blast, and that roughly that same area might be ablaze with fires within an hour after the explosion.

309. Possible consequences of megaton explosions over large cities were summarized in the United Nations study in 1980 (see figures 2 and 3). The United States Congress Office of Technology Assessment (OTA) in 1979 and the World Health Organization in 1984, as well as several independent organizations, have also dealt with the subject. Assuming only airbursts, which means disregarding the possibility of local fall-out with its associated additional casualties, the following table summarizes the results:

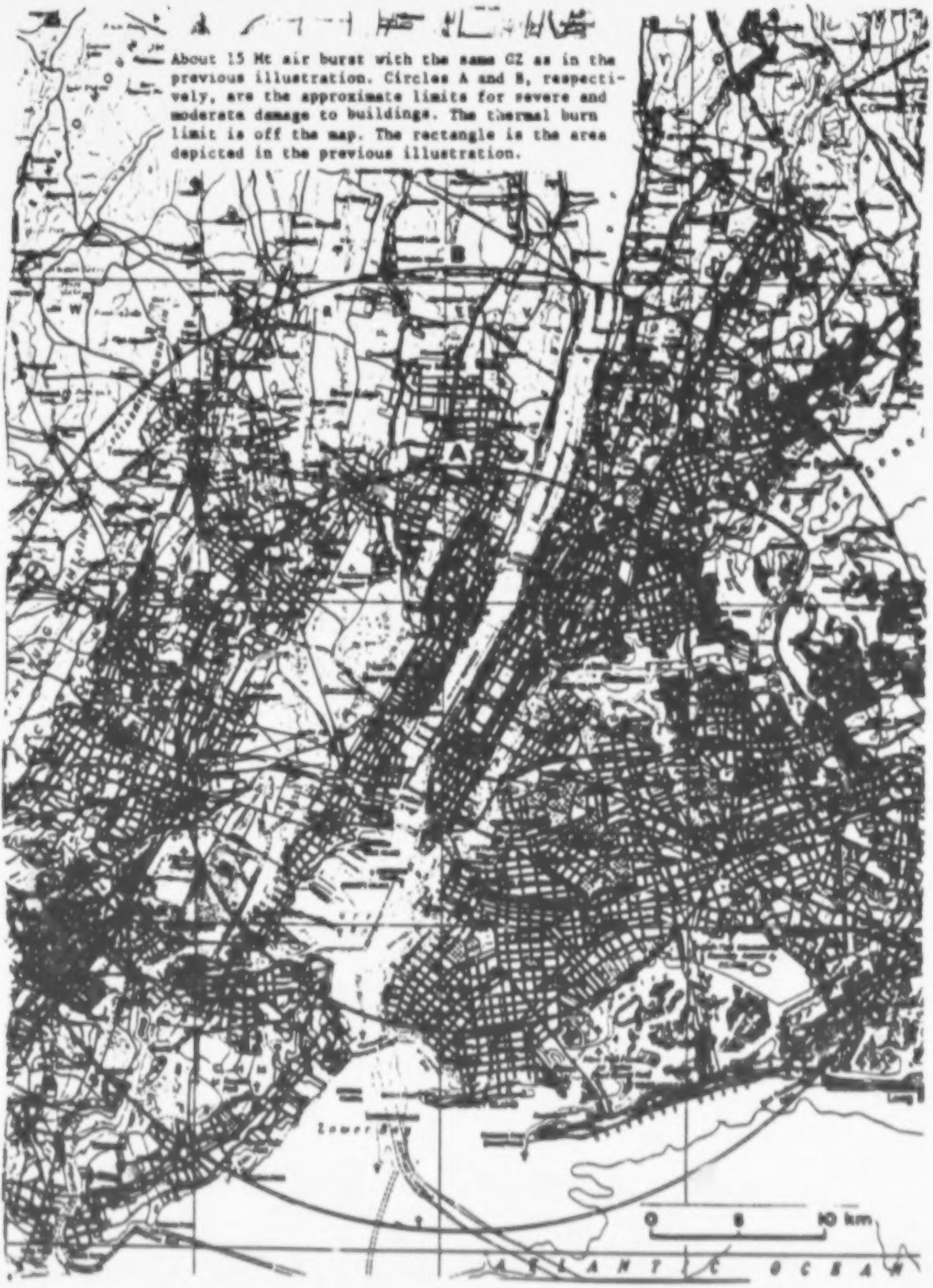
/...

Figure 2. A Hiroshima bomb over New York



About 15 kt air burst over Times Square in New York City. The limit for severe damage to buildings is somewhere in the tinted zone; it is rather uncertain what overpressure skyscrapers will withstand. The outer circle is the limit for third degree skin burns. (GZ = ground-zero)

Figure 3. 15 Mt air burst over New York



About 15 Mt air burst with the same GZ as in the previous illustration. Circles A and B, respectively, are the approximate limits for severe and moderate damage to buildings. The thermal burn limit is off the map. The rectangle is the area depicted in the previous illustration.

City	Weapon yield (Megatons)	Casualties (Millions) Killed	Total	Source
Detroit	1	0.5	1.1	OTA 1979 17/
Leningrad	1	1.0	2.0	OTA 1979 18/
New York	15		5-10	United Nations 1980 19/
London	1	1.6	3.2	WHO 1987 20/

310. As another example, an independent study group at Princeton 21/ estimated the casualties that would result if the 100 most populated regions in the United States and the Soviet Union were exposed to one 1 Mt airburst each. This was estimated to cause up to more than 70 million casualties, of which about 90 per cent would be killed outright, in the United States and even larger numbers in the Soviet Union. The resulting numbers may vary by a factor of up to 2, depending on what type of model is being used.

2. Consequences of a nuclear exchange

311. Most studies of the possible consequences of a nuclear exchange assume that a multitude of nuclear weapons are employed. These studies have some general points in common: (a) in any densely populated area, the ratio of civilians to military among those killed and injured would be very high; and (b) if ground bursts occurred, the number of casualties would rise significantly, owing to radiation injuries, since adequate shelters would not be available. The higher the yields of the explosions at ground surface the more important fall-out becomes. The number of civilians killed or injured by fall-out could far outnumber those affected by blast and heat.

312. Several studies have considered the consequences of a nuclear war in which all the weapons used are "tactical", having yields from 1 kt to some 100 kt, and are aimed at military targets. In some European scenarios, the number of explosions has been taken to be more than one thousand, with a combined yield in the range of 20-100 Mt, and the number of early deaths among civilians has been estimated to be between 10 and 20 million. 22/

313. Many studies of a major nuclear exchange, involving large numbers of strategic warheads, have been carried out, particularly in the United States. In these studies various scenarios have been described, generally categorized as either counter-force or counter-value strikes. 23/

314. In a counter-force strike, surface bursts would probably be used in large numbers, as they maximize the probability of destroying hard military targets, e.g. ICBM silos. The major cause of civilian casualties would then be early fall-out. Attacks against strategic bomber bases and strategic submarine bases might use air bursts and, to the extent that these facilities were located close to population centres, blast and thermal effects would cause considerable damage in such areas.

315. The United States Congressional Office of Technology Assessment (OTA) study published in 1979 quotes United States government studies indicating that between 2 and 20 million Americans would be killed within 30 days after a counter-silo attack on the United States ICBM sites. 24/ The same study concludes that a comprehensive counter-force attack on the United States would produce about 14 million dead even if the present fall-out shelter capability were utilized. A United States counter-force strike against the Soviet Union would result in somewhat similar numbers of casualties, according to OTA. The majority of fatalities within 30 days of a counter-force attack would be caused by radiation due to early fall-out from surface bursts. 25/ Other studies are in approximate agreement with these results.

316. In the studies referred to above, extensive sheltering of the civilian population is assumed. An uninterrupted stay in shelter during several weeks would be required to avoid still larger casualties. This would cause serious problems of sanitation, food and water supply, air filtration, health, communication to the outer world, psychological tensions, and so on.

317. After a counter-force strike, economic activities, especially in contaminated areas, would be disrupted for months and perhaps years. Furthermore, radioactive fall-out would cause serious problems to agriculture. Livestock would have little protection against fall-out. A severe decline in the supply of meat and dairy products would therefore result after a certain period of time and many years would be required to build up new livestock. Radiation effects on crops would depend on the season, an attack in spring causing more damage than one in the summer or early autumn. Radioactive elements filtering down into the ground water would be taken up by plants and, through grazing, by cattle and other animals. Quantities of radioactive substances could then enter the human system through consumption of foodstuffs from contaminated areas and contribute to the total number of late radiation injuries (see sect. D below).

318. The national capacity for food production, processing and distribution would probably be even more severely affected by an extensive counter-value attack than by a counter-force strike. Destruction of storage facilities, processing plants and transport facilities would result in a general food shortage within a short period of time. The destruction of virtually all petroleum refinery capacity, pipeline systems, and so on would have immediate consequences for transportation, heating and electrical power production. A counter-value attack could well entail the successive decay, if not the complete collapse, of social and political institutions.

319. The task of the survivors after a large nuclear war would be beyond our comprehension and they could face the complete breakdown of international order. In these circumstances reconstruction might be all but impossible.

/...

3. Consequences of damaging nuclear installations

320. The possibility must be taken into account that nuclear power industry installations, such as nuclear reactors, reprocessing plants or storage for spent nuclear fuel and radioactive waste, might be hit by nuclear explosions. Should this happen, most or all of their radioactive content might be surged into the explosion and add to the fall-out from the explosion itself. If one or a few such installations were destroyed, the additional amount of radioactive substances released would be limited. If, however, such installations were systematically targeted, the additional amount of radioactive substances released would be very substantial. 26/

321. The production rate of radioactive substances in a 1,000 MW nuclear electrical generating station is equal to that of one 60 kt atomic bomb every day, but after some time of reactor operation most of the short-life radiation would be limited to their saturation levels and the long-life radiation would dominate. In reprocessing plants and waste storages, only long-life radioactivity would remain. 27/ Because of this equilibrium, the activity released from a reactor would become gradually more important in comparison to that contained in the explosion debris as time goes by.

322. Systematic destruction of nuclear facilities would thus add marginally to the short-term radiation after the attacks, but after a week or so, the contribution from destroyed facilities to the radiation effects would dominate. In areas with many nuclear installations, like Europe, North America and Japan, destruction of these facilities would make large areas uninhabitable for a century or more. 28/ Comparison could be made with the Chernobyl accident, where part of the radioactive content of one reactor was released without the driving force of a nuclear explosion. 29/

D. Medical effects

323. During the 1980s, considerable attention was given to the study and description of the medical aspects of nuclear war. Generally speaking, injuries related to nuclear explosions fall into three groups - mechanical, thermal and radiation-induced - although all kinds of combinations are likely. 30/ Psychological effects would be likely to add to social disruption in a nuclear exchange. Mechanical injuries (fractures, soft tissue wounds, crush injuries) as well as thermal injuries (burns), are well known to medical science in general. In a nuclear context, though, problems would arise from the huge numbers of casualties and lack of resources. Acute radiation injuries, on the other hand, are uncommon in peacetime. The symptoms are often unspecific, at least initially, rendering the diagnosis uncertain. No specific remedies exist. In addition, delayed effects of radiation are quite different from acute radiation illness. 31/

/...

1. Mechanical and thermal injuries

324. An explosion may cause mechanical injury by overpressure acting directly on the human body or by causing the person to be swept away or dragged by the blast wind and thrown against a hard surface. The number of casualties is likely to be much higher after a nuclear explosion over a built-up area as a result of heavier material destruction, such as collapsing building structures, flying debris, and so forth.

325. Thermal injuries are mainly skin burns caused by the heat radiation (flash burns) or by fires ignited by this radiation (flame burns). In addition, the flash of heat and light might cause injuries to the eyes. Internal burns from inhalation of hot air or gases may occur in areas on fire, as well as toxic effects or asphyxiation from smoke and fumes. Flash burns, which are typical of nuclear explosions, are generated within a fraction of a second, whereas flame burns develop more slowly. The damage to tissue is not quite the same, as internal organs are more affected by the slower heating in flame burns. 32/

326. Moderate burns over 20 per cent of the body, or severe burns over 10 per cent, are considered to be grave even under circumstances favourable to treatment and healing. If no treatment at all is available, mortality from burn injuries will be very high. For instance, a 40 per cent burn might be fatal in one case out of five if medical treatment is optimal, but fatal in all cases if treatment is delayed for 24 hours. 33/

2. Radiation injuries

327. The most specific medical effects related to a nuclear explosion are the radiation injuries. 34/ Ionizing radiation from such explosions would always inflict some damage to biological tissue. Therefore, humans, animals and plants would be affected. Generally speaking, the larger the radiation dose, the more severe the resulting radiation injury to the organism. The injury to the individual caused by any given dose, would vary, however, depending on the species, age and general condition of the irradiated individual, the composition of the dose and the rate of irradiation.

328. Human radiation injuries can be of different types: acute radiation sickness, long-term effects that comprise an increased probability of late cancer and genetic effects, and short-term effects such as injuries in the prenatal stage and decreased immunological resistance.

329. A nuclear explosion would cause radiation injuries in several ways. Almost all of the initial radiation dose would be received from high-intensity radiation released within seconds in the immediate vicinity of the burst. This would be followed by the radiation from fall-out. The fall-out radiation emanates from particles outside the body, emitting harmful beta and gamma rays (external radiation). Large doses associated with early fall-out will be followed by lower intensity radiation received over a long period of time - from hours up to days, if it is possible to leave the area, otherwise much longer. There is some difference

in biological response, however: a slowly accumulated dose is generally considered less harmful than an equally large instantaneous dose, owing to recovery mechanisms. On the other hand, recovery mechanisms are overwhelmed in many cases of repeated exposure.

330. In addition to the external radiation, living tissue may be injured by radiation from radioactive substances in the fall-out that have entered the organism by breathing, eating and drinking. The radiation doses received from such internal sources are likely to be much smaller than early external doses from fall-out. On the other hand, internal doses might accumulate for long times in specific organs and may thus contribute significantly to late radiation injuries, in particular, cancers.

331. Some types of cells are more radio-sensitive than others, and consequently certain organs or functions are disturbed at lower dose levels than others. The stem cells in the bone marrow, which produce various types of blood cells, are highly radio-sensitive. Hence, the so-called bone-marrow syndrome, characterized by low levels of certain blood cells, including lymphocytes, dominates the radiation response of the human body at moderate dose levels. Before this syndrome appears, however, there are other, unspecific symptoms called "prodromal". The term "acute radiation sickness" covers the prodromal stage, the bone-marrow syndrome and the gastro-intestinal and neurovascular syndromes appearing at higher doses. 35/

332. For the reasons described above, an important form of treatment of radiation injuries would be to prevent or reverse infections by providing the patients with the cleanest possible environment, preferably in isolated wards, and by using antibiotics, antimycotics and blood transfusions. Resources of these kinds will most likely be scarce or unavailable in the aftermath of a nuclear war.

333. Those who survive an acute radiation injury stand a larger risk than others of contracting certain diseases, in particular various forms of cancer. These afflictions are called late radiation injuries, as they may remain latent for years or decades before manifesting themselves. Even if the radiation exposure was not large enough to cause a state of acute sickness, it would produce an increased risk of late cancer. Radiologists now estimate the cancer risk per unit dose to be about five times higher than previously thought. This means that 5 to 10 cases per man-gray 36/ are expected instead of 1 to 2 cases.

334. When the exposure is an essentially uniform, whole-body irradiation from an external source, the total risk mentioned above is the sum of specific risks for different types of cancer, among which leukaemia, lung cancer and possibly stomach cancer are the most common. Exposure to radiation from internal sources will add to the overall dose received by a particular organ. Certain radio-nuclides accumulate in some organs. 37/

335. Radiation at much lower dose levels seems to be harmful to the human foetus, especially during the first four months or so of gestation. An exposure *in utero* can give rise to malformations, mental retardation and increased susceptibility to serious diseases, including childhood cancers, in addition to an increased risk of pre-natal or neo-natal death.

336. Furthermore, it is known that radiation affects the gonads (ovaries and testicles) and that radiation-induced mutations may then appear in the reproductive cells. It has been suggested that the changes may be transmitted to live offspring, thereby constituting a genetic damage that could become manifest in that or future generations. However, it is very difficult to assess the precise relationships between radiation doses and genetic damage in humans. The data available is insufficient to demonstrate genetic damage among the offspring of Hiroshima and Nagasaki survivors, for instance.

337. The 1980 United Nations study assumed in a "worst case scenario" that the source of radiation would be global fall-out from 10,000 Mt total explosive yield. It quotes one consequence of this to be between 5 and 10 million excess fatalities from cancer over a period of about 40 years. The recent scientific findings, as adopted by UNSCEAR, 38/ would indicate corresponding numbers of 25-50 million, with an additional number of non-lethal tumours (including thyroid cancer) totalling perhaps 10 million. The cases of hereditary ill health caused by radiation may number a million or so in the first two generations and several million over the indefinite future.

3. Other health effects

338. There are other long-term factors that must be taken into account. The need for medical care would obviously be most acute during the first hours or days following a nuclear exchange. For instance, one nuclear explosion could produce tens of thousands of burn victims. In view of the fact that the United States has facilities to treat about 2,000 serious cases of burns and Western Europe about 1,500, it is clear that even peacetime resources would be quite inadequate to manage the casualties. 39/ Moreover, peacetime resources will not be available, as the qualified medical services either would be destroyed by the nuclear explosions or, if they are intact, may be too remote from the scene to be efficiently used. 40/

339. Furthermore, it is likely that production of medical supplies would be severely disturbed if major cities were attacked. Shortages of antibiotics or vaccines, for instance, would affect the whole world. The same would most likely hold true for other products, such as pesticides and detergents, which are needed to maintain hygienic standards and to fight different vectors of epidemic diseases. The severe food shortages and starvation that would be likely to occur in the aftermath of a major nuclear war would add considerably to the detrimental effects on global health. 41/

E. Environmental and other global effects

340. It has long been recognized in principle that certain consequences of a major nuclear exchange would not be possible to limit to the territories of nuclear-weapon States, or the territories of other nations being included in the nuclear exchange. This fact has become more widely accepted during the last few years, concomitant with new findings that add further dimensions to the projections of the global aftermath of such an exchange.

1. Climatic effects

341. The question of climatic perturbations has been thoroughly studied in the last decade. The analyses done up to 1980 had focused largely on the possible changes in the climate due to the injection of dust into the atmosphere caused by nuclear explosions. The new analyses first carried out in 1982 took into account in their calculations an additional element, i.e. the effects of widespread fires that would be ignited by the nuclear explosions. The new estimates of the cooling effects, brought about by the absorption of sunlight in the clouds of smoke, were considered so dramatic that the term "nuclear winter" was coined to describe them. 42/

342. During the following years, a substantial amount of additional research was carried out to explore more thoroughly the possible atmospheric changes induced by different forms of nuclear warfare, as well as the biological consequences of such changes. The most comprehensive study carried out so far is that made by the Scientific Committee on Problems of the Environment (SCOPE), a committee organized by the International Council of Scientific Unions. The results of this and other studies were summarized in a recently published United Nations study, the most relevant parts of which read as follows: 43/

> "The scientific evidence is now conclusive that a major nuclear war would entail the high risk of a global environmental disruption. The risk would be greatest if large cities and industrial centres in the northern hemisphere were to be targeted in the summer months. During the first month, solar energy reaching the surface in mid-latitudes of the northern hemisphere could be reduced by 80 per cent or more. This would result in a decrease of continental averaged temperatures in mid-latitudes of between 5° to 20° C below normal within two weeks after the injection of smoke during summer months. In central continental areas individual temperature decreases could be substantially greater. ... Recent work ... suggests that these effects might be compounded by a decrease in rainfall of as much as 80 per cent over land in temperate and tropical latitudes. The evidence assessed to date is persuasive that residual scientific uncertainties are unlikely to invalidate these general conclusions.
>
> "Beyond one month, agricultural production and the survival of natural ecosystems would be threatened by a considerable reduction in sunlight, temperature depressions of several degrees below normal and suppression of precipitation and summer monsoons. In addition, these effects would be aggravated by chemical pollutants, an increase in ultraviolet radiation associated with depletion of ozone and the likely persistence of radioactive 'hotspots'.
>
> "The sensitivity of agricultural systems and natural ecosystems to variations in temperature, precipitation and light leads to the conclusion that the widespread impact of a nuclear exchange on climate would constitute a severe threat to world food production."

343. The residual scientific uncertainties mentioned above pertain to virtually all steps in the physical processes involved. Some examples of these uncertainties are the amount and characteristics of combustible materials that will burn after a specified explosion, the amounts of smoke and soot produced by the combustion, the optical and other properties of the smoke particles and the altitude to which the smoke rises. In addition, mathematical models used to simulate dynamic processes in the atmosphere must always be simplifications. However, much of the original uncertainty has been resolved through experimental research since 1983. Concurrently, more sophisticated models for numerical analysis of atmospheric processes have been employed. It should be recalled, however, that the basic uncertainties associated with the war scenarios, such as choice of weapon yields, targets, and so on cannot be resolved by science.

2. Ozone layer effects

344. In addition to global climatic effects, the use of nuclear weapons is expected to affect the ozone layer as well. The fireball from a nuclear explosion heats the air to temperatures where oxygen and nitrogen molecules dissociate. In the subsequent cooling, a number of different nitrogen oxides are formed. It is estimated that a 1 Mt explosion would produce 5,000 tons of such oxides. In a large nuclear exchange the quantities of nitrogen oxides injected into the upper atmosphere would be considerably higher. These oxides would then reach the ozone layer in the stratosphere and might, through chemical reactions, partially destroy it in a few months. 44/

345. The extent to which the release of a given quantity of nitrogen oxides would deplete the ozone layer is not entirely clear. It is believed, however, that some 50 per cent of the ozone column might be depleted in a major nuclear exchange taking place during the summer months. In winter conditions the percentage would be smaller (some calculate 10-20 per cent).

346. Irrespective of the percentage of ozone layer depletion, the depletion would produce a number of harmful effects. For instance, since ozone is an effective barrier to solar ultraviolet radiation, its depletion would result in an increase of this radiation at the surface of the Earth. Although the full biological implications of increased ultraviolet radiation to ecosystems at various latitudes are not known, skin cancer is related to large amounts of ultraviolet radiation. Plants and animals might also be affected. Ocean phytoplankton, the basis of the world food chain, has been shown to be particularly sensitive.

3. Other effects

347. Other world-wide effects of a major nuclear exchange are difficult to examine and assess. However, the fact that today's world is characterized by a large, intricate and increasing international interdependence in all aspects of life strongly suggests that significant global economic and social disruptions would be an unavoidable consequence of such an exchange.

/...

348. In the first place, all countries in the world, combatants as well as non-combatants, would suffer a drastic reduction of foreign trade. This would be due to factors such as a decrease in production volume both of essential commodities and raw materials, disruption of services and breakdown of the organization of world commerce and communications. The world food supply and production would also be imperilled by trade disruptions. It is also expected that climatic perturbations would have some impact on agriculture in any major war scenario.

349. The 1980 United Nations study on nuclear weapons gave an indication of the possible global food situation after a nuclear exchange, without considering additional climatic problems. The 1985 study by the Scientific Committee on Problems of the Environment, 45/ however, provided more analysis of the vulnerability to losses of agricultural productivity and the potential for recovery of food production as well as various assumptions regarding the climatic disturbances. A simplified assessment was made for some 120 other countries. The results were, in brief, that very few countries had a capability to support their populations either in the short term, by using stored food, or in the longer term, by resuming or maintaining agriculture at the levels permitted by drastically reduced trade and by an altered climate. Between several hundred and about two thousand million people globally would be at risk of serious food shortages following a large nuclear exchange. The actual numbers of starving people, as well as the duration of the famines, depend on scenario assumptions. It is important to note, however, that famines, with possible mass death due to starvation, are likely to occur in non-combatant countries as well as in combatant ones, and even in countries remote from the theatres of war. The most vulnerable countries are developing nations in Africa, Asia and South America.

350. These conclusions of the SCOPE study are in general agreement with the findings of other independent studies, as well as with those of the 1980 United Nations study. They all note that eventually the victims of the indirect, large-scale and long-term effects of a major nuclear war would far outnumber the victims of the immediate effects of the nuclear explosions.

F. Possible protective measures

351. A number of nations, especially in Europe, have organized a civil defence to meet the demands of a conventional war, with or without additional features specifically designed for nuclear war situations. Basically, all measures aim at short-term needs.

352. Some of these measures could help to limit the number of immediate fatalities caused by a nuclear attack. In view of the large devastation that would be caused, however, especially if nuclear weapons were used directly against the population, available resources for post-attack relief could prove totally inadequate. The value of protective measures in the case of a major nuclear exchange is a matter of dispute. There are those, however, who contend that a war might turn out to be limited in some sense and that it would be reasonable to undertake such protective measures as are technically and economically feasible.

/...

353. Civil defence could, for instance, be very effective in saving lives that would otherwise be lost to fall-out in a limited attack against hard targets. On the other hand, it would be far less effective in a war involving strikes against industry in cities, or against the civilian population as such. This holds true for non-nuclear-weapon States as well as nuclear-weapon States in a nuclear war. Even in countries that do not themselves come under a nuclear attack, civil defence would be needed to deal with fall-out from large numbers of nuclear explosions in neighbouring countries.

354. After a nuclear attack (and to some extent after fall-out contamination originating from an attack elsewhere) there would be a need for food, energy, medical supplies, clothing and provisional housing. Crisis stockpiling of basic supplies would be an important precaution for dealing with these difficulties during the first days or weeks. However, allocation and distribution of emergency supplies would have to be carefully planned.

355. In discussing the question of civil defence, some analysts have endeavoured to compare the Chernobyl nuclear reactor accident of 1986 with the possible aftermath of a nuclear war. Although the circumstances would be different because Chernobyl involved only a release of radiation, with no associated blast damage, they believe this experience points to the kind of difficulties that would ensue after a nuclear exchange. For example, at Chernobyl the civil defence efforts were inadequate to deal with the situation. In a nuclear war, the magnitude of the problems related to civil defence would be greatly increased.

Notes

1/ For more detailed descriptions of a nuclear explosion of the type that was exploded in Hiroshima and Nagasaki, see the Committee for the Compilation of Materials on Damage Caused by the Atomic Bombs in Hiroshima and Nagasaki, The Impact of the A-Bomb, Tokyo, Iwanamu Shoten Publishers, 1985, pp. 59-84. For a theoretical scenario involving modern nuclear weapons, see Office of Technology Assessment, The Effects of Nuclear War, Washington, D.C., US Government Printing Office, 1979, pp. 13-48. For a technical discussion, see L. W. McNaught, Nuclear Weapons and Their Effects, London, Brasseys, 1984, chap. 3; as well as Samuel Glasstone and Philip J. Dolan, eds., The Effects of Nuclear Weapons, Washington, D.C., US Government Printing Office, 1977, chaps. I-IV.

2/ For a weapon with a yield of 10 to 20 kt, i.e. that of the Hiroshima and Nagasaki bombs, the maximum radius is approximately 200 m and its development takes about one second.

3/ See McNaught, op. cit., pp. 26 and 27.

4/ Ibid., pp. 37-46. See also Glasstone and Dolan, op. cit., pp. 282-296 and chap. VII in general.

5/ See McNaught, op. cit., pp. 79 and 80. See also Glasstone and Dolan, op. cit., pp. 45-48, and chaps. III-V for extensive discussions of air blasts and their effects.

/...

Notes (continued)

6/ Ground-zero is the point on the Earth's surface where a nuclear weapon is detonated; for an airburst it is the point on the Earth's surface directly below the point of detonation.

7/ See McNaught, op. cit., pp. 49-58. See also Glasstone and Dolan, op. cit., chaps. VIII and IX.

8/ See McNaught, op. cit., pp. 95-106. See also Glasstone and Dolan, op. cit., chap. XI.

9/ See Glasstone and Dolan, op. cit., pp. 594-608.

10/ Ibid., pp. 36-38.

11/ Ibid., pp. 33-38.

12/ The uncertainties are illustrated by the bombings of Japan. The Hiroshima bomb, estimated to be 13 kt, killed and injured about twice as many people as a larger bomb, 22 kt, used in Nagasaki. The discrepancy between the two outcomes has been attributed to the different topography of the two cities.

13/ See Glasstone and Dolan, op. cit., pp. 96-105.

14/ Ibid., pp. 604-613.

15/ See ibid., chap. XI, for an in-depth discussion of the electromagnetic pulse and its effects. See also McNaught, op. cit., pp. 95-106, for a short technical discussion.

16/ See The Impact of the A-Bomb, op. cit., pp. 22 and 25, for Hiroshima and pp. 47 and 48 for Nagasaki casualty figures.

17/ The Effects of Nuclear War, op. cit., p. 37.

18/ Ibid.

19/ Numerical estimates were made for the United Nations Study Group at the Swedish National Defense Research Institute.

20/ World Health Organization, Effects of Nuclear War on Health and Health Services, 2nd edition, Geneva, WHO, 1987, p. 22.

21/ W. H. Daugherty, B. G. Levi and F. N. von Hippel, Casualties Due to the Blast, Heat and Radioactive Fallout from Various Hypothetical Attacks on the US, Princeton University, Center for Energy and Environmental Studies Report No. 198, 1986.

/...

Notes (continued)

22/ See *Comprehensive Study on Nuclear Weapons*, *op. cit*., paras. 198-212. See also C. F. von Weizsäcker, ed., *Kriegsfolgen und Kriegsverhütung*, Munich 1971; *Ambio* (Journal of the Swedish Royal Academy of Sciences), Vol. XI, 2-3 (Special Issue) 1982, pp. 163-173; WHO, *Effects of Nuclear War on Health and Health Services*, *op. cit*.

23/ See Charles-Philippe David, *Debating Counterforce*, Boulder, Westview Press, 1987, especially pp. 165-214.

24/ *The Effects of Nuclear War*, *op. cit*. This study does not specify the numbers, yields and heights of burst of the nuclear weapons employed. Rather it is assumed that the attacks are sufficient to destroy all or a certain part of the other side's nuclear weapons installations.

25/ *Ibid*., pp. 31 and 32.

26/ See Bennett Ramberg, *Nuclear Power Plants as Weapons for the Enemy*, Los Angeles, University of California Press, 1980. See also WHO, *Effects of Nuclear War on Health and Health Services*, *op. cit*., pp. 50 and 51.

27/ S. A. Fetter and K. Tsipis, *Scientific American*, 244, 33 (1981); J. Peterson, *The Aftermath*, Pantheon, New York, 1983; J. Rotblat, *Nuclear Radiation in Warfare*, SIPRI, Taylor and Francis, London, 1981.

28/ See Ramberg, *op. cit*., pp. 71-109.

29/ See David R. Marples, *Chernobyl and Nuclear Power in the USSR*, New York, St. Martin's Press, 1986, pp. 115-152, for a discussion of the accident at Chernobyl.

30/ *Effects of Nuclear War on Health and Health Services*, *op. cit*.

31/ For a discussion of the medical effects of nuclear war, see the WHO study, *op. cit*.; the National Academy of Sciences and Institute of Medicine, Frederic Solomon and Robert Q. Marston, eds., *The Medical Implications of Nuclear War*, Washington, D.C., National Academy of Sciences Press, 1985; Ruth Adams and Susan Cullen, eds., *The Final Epidemic, Physicians and Scientists on Nuclear War*, Chicago, Educational Foundation for Nuclear Science, Inc., 1981; also Saul Aronow, Frank R. Erwin and Victor W. Sidel, eds., *The Fallen Sky - Medical Consequences of Thermonuclear War*, New York, Hill and Wang, 1963; Glasstone and Dolan, *op. cit*., for biological effects of nuclear weapons, chap. XII.

32/ See Glasstone and Dolan, *op. cit*., pp. 560-574. See also Jennifer Leaning, "Burn and Blast Casualties: Triage in a Nuclear War", in Solomon and Marston, eds., *The Medical Implications of Nuclear War*, *op. cit*., pp. 251-283.

33/ *Ibid*.

/...

Notes (continued)

34/ For a discussion on radiation, see Effects of Nuclear War on Health and Health Services, op. cit., pp. 18-20; Glasstone and Dolan, op. cit., pp. 541-618; The Impact of the A-Bomb, op. cit., chaps. 5, 6, and 8; Patricia Lindop and Joseph Rotblat, "Consequences of Radioactive Fallout" in Adams and Cullen, op. cit., pp. 117-150; Joseph Rotblat, "Acute Radiation Mortality in a Nuclear War", and David Greer and Lawrence Rifkin, "The Immunological Impact of Nuclear Warfare", both in Solomon and Marston, op. cit., pp. 233-250 and pp. 317-328.

35/ The LD 50/60, i.e. the dose that causes 50 per cent fatalities within 60 days, has been repeatedly revised downwards. In a situation where medical treatment is not available, it is now thought by radiologists to be about 2.3 Gy to the bone marrow. Under similar conditions, doses above 4.5 Gy should be considered lethal, with death generally occurring within a few weeks. Gy stands for gray, which is the internationally accepted unit for radiation dose. With regard to radiation from a nuclear explosion or from early fall-out, gray is approximately equivalent to sievert.

36/ Man-sievert is a common unit for "collective equivalent dose", i.e. the average equivalent dose to a group of people, multiplied by the number of people in the group.

37/ In this regard, it is of particular importance, especially for children, to prevent radioactive iodine-131 from entering the body within the first weeks or so, since it concentrates in the thyroid glands, with subsequent high risks of contracting thyroid cancer. If strontium-90 and caesium-137 are in ingested food, strontium will be deposited in the bone, causing possible bone cancer, leukaemia, etc., and caesium will be distributed roughly evenly throughout the body. See Glasstone and Dolan, op. cit., pp. 583-587.

38/ Sources, Effects and Risks of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation 1988 report (United Nations publication, Sales No. E.88.IX.7).

39/ See Leaning, op. cit., and John Constable, "Burn Casualties", in Adams and Cullen, op. cit., pp. 182-191.

40/ For example, in Hiroshima, more than 90 per cent of physicians and nurses in the city were killed by the explosion.

41/ See Alexander Leaf, "Food and Nutrition in the Aftermath of Nuclear War", in Solomon and Marston, op. cit., pp. 284-289.

42/ See Paul R. Ehrlich, Carl Sagan, et al., eds., The Cold and the Dark - The World After Nuclear War, New York, Norton, 1984, in particular Carl Sagan's chapter on "The Atmospheric and Climatic Consequences of Nuclear War", pp. 1-40. See also the National Research Council, The Effects on the Atmosphere of a Major Nuclear Exchange, Washington, D.C., National Academy Press, 1985.